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Vol. VI, No. 21

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BY PROF. S. W. WOOLDRIDGE

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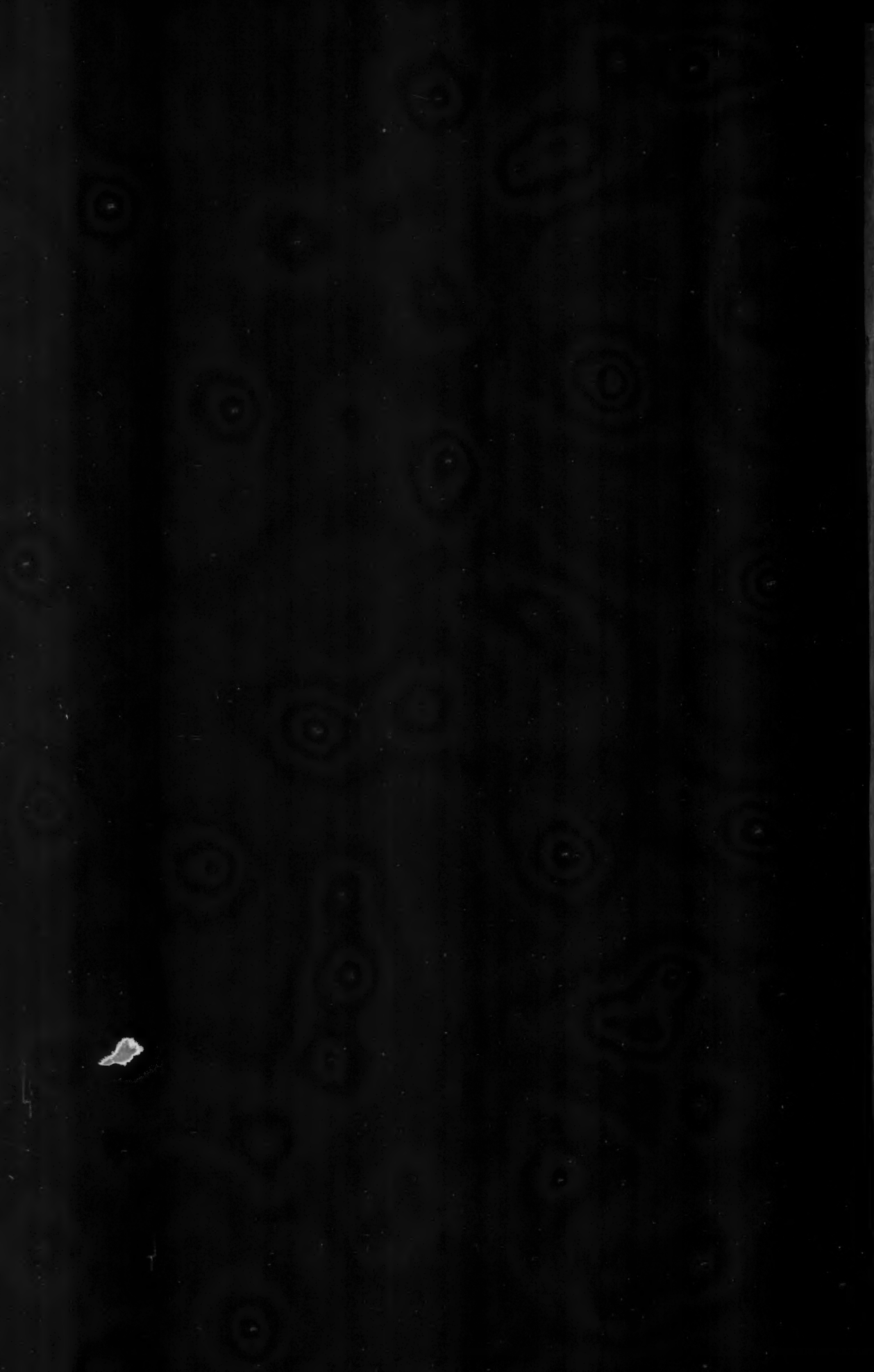

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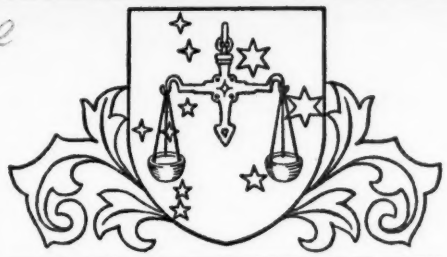

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THE ADVANCEMENT OF SCIENCE

VOL. VI, No. 21 APRIL, 1949

CONTENTS

PAGE

OFFICERS AND COUNCIL 2

THE WEALD AND THE FIELD SCIENCES. *by* PROF. S. W. WOOLDRIDGE 3

THE PHYSIOLOGY OF LACTATION—REPORT OF A SYMPOSIUM, *by* DR. K. L. BLAXTER 12

PROBLEMS OF OLD AGE—REPORT OF A SYMPOSIUM 15

TECHNIQUE AND ECONOMIC ORGANISATION AMONG PRIMITIVE PEOPLES, *edited by* ADRIAN DIGBY 23

THE CONTRIBUTION OF INSTRUMENTS TO INDUSTRIAL PROGRESS, *by* SIR EWART SMITH 29

BIOLOGY IN THE EDUCATIONAL CURRICULUM—REPORT OF A DISCUSSION 33

SOME POST-WAR ECONOMIC DEVELOPMENTS IN EGYPT, *by* A. MCK. FROOD 45

THE TRAINING OF THE GEOLOGIST—REPORT OF A DISCUSSION, *by* PROF. T. N. GEORGE 51

THE TEACHING OF GEOLOGY IN SCHOOLS—REPORT OF A COMMITTEE 55

SEISMOLOGICAL INVESTIGATIONS—REPORT OF A COMMITTEE 56

NON-LINEAR VIBRATIONS—REPORT PREPARED *by* DR. MARY L. CARTWRIGHT, F.R.S. 64

SECTION J.—PSYCHOLOGY ; ABSTRACTS OF COMMUNICATIONS 76

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THE WEALD AND THE FIELD SCIENCES[1]

BY

PROF. S. W. WOOLDRIDGE

ANDRED'S WEALD was the name given by the Anglo-Saxon invaders of this country to the great tract of forest, about 100 miles long and, at its broadest, 40 miles wide, lying between the Chalk tracts of the North and the South Downs. To the earlier Romans it had been Silva Anderida and for them as for their successors it was a great area of 'waste,' difficult to traverse, lying between the more penetrable lands of the south coast and the Thames valley. It is still one of the most heavily wooded areas in Britain. By Elizabethan times the piecemeal clearing of the forest to provide timber, charcoal for smelting the local iron-ores, and to free the ground for cultivation, had made considerable progress, but viewed from the many hill-top vantage points on its margins it still has the aspect of a forest, for woodland and coppice account for much of the surface and hedge-row timber is abundant and well-grown. But as man cleared the timber he revealed the lineaments of a singularly beautiful and impressive landscape which illustrates to perfection the interrelationship of natural phenomena, the gearing in a complex harmony of rocks, soils, hills, valleys, vegetation, animal and human life.

In the narrower sense the historic Weald—the 'wild' of Defoe, was essentially the central 'waste' inside the more habitable fringes. These fringes certainly included the Chalk country, and in Kent, also the inner hill country on the Lower Greensand. In Surrey, Sussex and Hampshire, however, the latter was essentially within the Weald in that it was part of the sparsely settled wilderness. Geologists and geographers, impressed by the unity of structure of the wider region of which it forms part, customarily and legitimately use the term Weald in a wider sense as comprising the whole area involved in the great dome-shaped uplift of the Chalk. For scientific study this is the preferable usage, for much of the interest of the area lies in the contrasts between its centre and its fringes.

The field sciences are here taken to include, primarily, geology, geomorphology, the borderline field which it shares with geography, pedology, plant and animal ecology, archaeology and the group of converging studies which constitute the rapidly developing field of human or social geography.

Of these field sciences geology is the basic member in somewhat the same sense as physics is basic to natural science as a whole and to all the laboratory crafts. The laboratory, as the place of controlled experiments, is central in the life of the scientist, dominantly so in the case of physics and chemistry, increasingly so in the field of biology and even in those of geology and geography. But a very wide group of investigations derive much of their stimulus and almost all their evidence from work in the field. Certain famous British regions, of which the Weald is conspicuously an example, have served as true field laboratories in this sense. The aim of the following pages is to indicate something of the contribution of the Weald to the field sciences—to natural history in the widest sense of the term—and to pay a tribute to the men who have studied them. The first visit of the British Association to Brighton in 1872, affords us a convenient landmark in the history of research in the area and the recent visit in 1948, after a lapse of three-quarters of a century, offers occasion to register the progress of the years between.

From the geological standpoint the Weald is essentially a window opened up in a thick mass of Lower Cretaceous sands and clays beneath the formerly over-arching Chalk which to-day forms the selvage to the piece. The lower part of the succession comprises the thick fresh-water Wealden formation, which is thin or absent north of the Thames. Thus William Smith, coming over the North Downs, expected to find Jurassic rocks exposed. In his earlier work he confused the local Lower Greensand with the rocks of Portland and their equivalents and took the Weald Clay for the Kimmeridge Clay. But local workers of whom the chief was perhaps Fitton steadily elucidated the succession, and Smith himself corrected his former errors after his appointment as engineer to the Ouse Navigation in 1809. The Wealden beds for long remained an enigmatical formation in many respects. In them Gideon Mantell made the first discovery of the great herbivorous dinosaur, *Iguanodon*, though the best authorities of the day misidentified the earlier found remains as those of rhinoceros and hippopotamus. The mounting tale of fishes, plants and mollusca served ultimately to establish the fresh water origin of the beds. Not, however, till the Geological Survey began their work in the area in 1855 were the Hastings Sands subdivided by Frederick Drew into the formations now recognized.

[1] Evening Discourse to the British Association delivered in the Royal Pavilion, Brighton, on September 10, 1948.

The upper member of the Wealden, the Weald Clay is still not effectively sub-divided, and our ignorance of the detailed succession within it greatly hinders structural interpretation in some areas. It may be remarked in passing that it is high time that an attempt was made to study the ostracod faunas, as has been done in Germany. But all such problems were far ' below the horizon ' when the Geology Section met at Brighton in 1872 and heard the address from its President—Godwen-Austen—on the Wealden Formation. Three years later the Geological Survey memoir of the Weald appeared and in it Topley discusses at length the conditions of formation of the Wealden. It was commonly regarded, then and later, as a lacustrine formation, but since the supposed ' lake ' has no ascertainable southern shores it is now considered more probable that we are dealing with the deposit of a delta. The question of the attribution of the Wealden to the Cretaceous or to the underlying Jurassic rocks, which follow conformably, was long debated. It involves the difficulty, in the words of T. H. Huxley, of using sea-reckoning for land-time but on balance of evidence a Lower Cretaceous age has latterly been preferred.

Most of the problems of succession and correlation in the Weald thus concerned and still concern the Wealden formation. The overlying beds comprising the Lower Greensand, Gault and Upper Greensand were wrongly associated together by Murchison in his ' Greensand formation ' which was a misnomer in several respects. It seems probable that the real division between the Lower and the Upper Cretaceous occurs within the Gault. The Lower Greensand of the Weald presents a number of rapid variations in lithology or local facies, and its recognized divisions, the Atherfield Clay, Hythe Beds, Sandgate Beds, and Folkestone Sands have, at present, little or no palaeontological basis. A great deal of work remains to be done on this formation, though the more recent efforts of H.M. Geological Survey, and the late F. Gossling and of Dr. J. F. Kirkaldy, both of the Weald Research Committee, represent a beginning on the task.

The Upper Cretaceous rocks of the Weald show features common to a much wider region and are known in considerable detail. Since the first Brighton meeting the most notable advance was the detailed sub-division of the Gault at Folkestone by de Rance and Price (1879) and from these beginnings the still more refined work of L. F. Spath has proceeded. The classic work of H. W. Rowe on the Chalk genus *Micraster*, and of the succeeding indefatigable group of Chalk palaeontologists has not concerned the Weald as such, though applicable to the whole of the Wealden Chalk. A tribute is due, however, to the recent patient work of C. T. A. Gaster which bids fair to provide us with a complete zonal map of the South Downs.

With some special exceptions, such as we have briefly noted, it is not the pure stratigraphy of the Weald which has contributed most to the general theory of geological science but rather the problems of its structure and denudation. The structure of the Weald is commonly misrepresented in simple cross-sections with exaggerated vertical scales. Superimposed on the broad dome or pericline, of which the Boulonnais of France forms the dissevered eastern continuation, there are well-marked longitudinal folds associated with strong faulting. The Weald, in fact, is not a simple anticline, but an ' anticlinorium,' if we may use an ugly but expressive word for which there is no ready substitute. The general doming about a ' strata-crest ' passing through Handcross on the Brighton road was fully and correctly perceived by John Farey as early as 1805 and he seems to have been the first to recognize the scale and significance of what he termed ' the great southern denudation '—the unroofing of the dome. Farey made his preliminary observations from the stage-coach, a fact which gave occasion for rather contemptuous comment from Bakewell and Playfair. One wonders how many enjoying the advantages of modern transport across the Weald see as much.

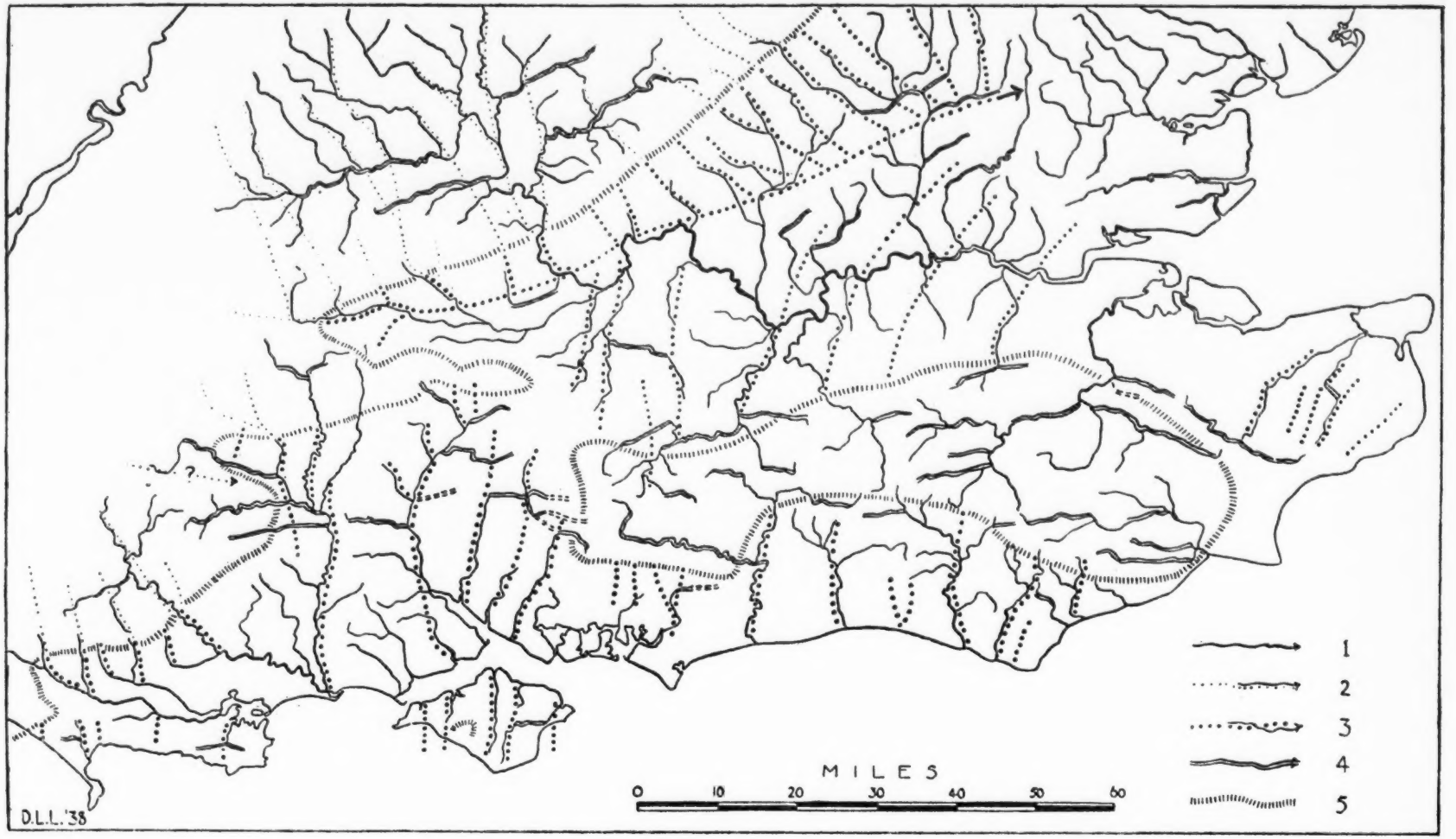
A tolerably accurate picture of the local folding and faulting within the Weald was known to Topley and his co-workers as well as to earlier students such as the Cambridge mathematician Hopkins who speculated on the mechanics of the structure. We have not advanced far beyond the stage they reached except on the Wealden margins where Geological Survey revision is well advanced. It is a sobering and unwelcome thought that we are probably more ignorant of the detailed structure of the Central Weald, including the great wilderness of Weald Clay, west of Horsham, than of any comparable tract in the English Lowland. More active research and speculation has been brought to bear upon the ' under-structure ' of the Weald. The starting point was the prescient inference of Godwen-Austen in 1856 that coal measures would be found to exist in the Palaeozoic floor beneath South East England. At the Brighton meeting of 1872 Topley discussed the proposed Sub-Wealden boring at Battle, planned by Henry Willett in honour of the Association's visit. He estimated that the Palaeozoic rocks would be entered at a depth of about 1600 ft. But the first boring did not reach the floor and later evidence showed that there and elsewhere, as at Penshurst

near Tonbridge, it must lie at considerably greater depth. The subsequent discovery of the Kent coalfield and its exploration provided G. W. Lamplugh with further data from which he concluded that the Wealden pericline corresponded with a species of subsurface trough in the Palaeozoic floor, towards the centre of which both the Lower Cretaceous and sub-Cretaceous rocks thickened. It is a well-attested fact that there is a northward thinning of all the strata up to and including the Lower Greensand, against the rising surface of the Palaeozoic floor in the London area. The structure inferred by Lamplugh assumed a similar southward rise of the floor, bringing it back to shallow depth beneath the English Channel. This ingenious suggestion had much to commend it, but, as several workers pointed out, it could not really be sustained on the evidence available to Lamplugh. It was finally disproved by the explorations of the Anglo-Iranian Oil company in 1937. At Henfield a boring, starting in the Wealden, traversed nearly 4000 ft. of Jurassic rocks to enter the floor at a depth of 4890 ft. Similarly at Portsdown a boring was carried to a depth of 6556 ft. without reaching the floor and the Jurassic succession is even thicker than at Henfield. It is thus clear that there is no general tendency for the Sub-Wealden strata to thin out southwards and Lamplugh's picture of the Weald as a symmetrical bi-convex structure, anticline above syncline, must be abandoned.

Turning now to the problems of the denudation of the Weald we must return to the era before the first Brighton meeting to find the beginnings of thought and observation. To Lyell speaking of the familiar view along the South Downs viewed eastwards or westwards from the Devil's Dyke, (in the First Edition of his Principles of Geology 1837) it was clear that the escarpment showed ' the exact likeness to a sea-cliff ' and ' the different projecting masses of Chalk ' were to him the headlands of a former coast. We cannot here trace in full the subsequent controversy between the supporters of marine and subaerial action. Greenwood in his ' Rain and Rivers ' (1857), gave the first clear statement of the later view—viz. that ' the ridges . . . instead of being considered as barriers to the rivers have actually been formed by the rivers by the abstraction of the intervening masses.' A full analysis of the differences between cliffs and escarpments from the pen of Whitaker came ten years later in a paper then regarded as so controversial, or perchance unsound, as to be rejected by the Geological Society of London. But Topley tells us that Drew who had left the Geological Survey in 1862, after seven years work, had already abandoned the theory of the marine origin of the escarpments, and the clinching arguments produced by Topley and Le Neve Foster in their paper of 1865 finally demonstrated the efficacy of sub-aerial denudation in the area.

But though marine action was banished from the field of escarpment sculpture, all the earlier workers surmised that it had been active at an earlier date and at higher levels in producing a plain of marine denudation of which the higher hill-tops were surviving portions. The evidence for a hill-top plain was seen in the accordant levels of the ridge crests. To Ramsey, considering a similar hill-top plain in South Wales it seemed evident that such a surface could only be produced by the waves of the sea, and the same argument was applied to the Weald without any serious attempts to discover the date and extent of the sea in question. This view, or some variant of it, held the field for almost thirty years until W. M. Davis paid his fruitful visit to this country in 1895. In his paper ' On the origin of certain English Rivers ' he argued that the characters of the Wealden drainage implied successive cycles of subaerial denudation, the first culminating in a peneplain represented by the higher hill-tops. We need not recall here all the arguments used to support this conclusion. In essence, his case was that the degree of adjustment to structure of the Wealden drainage was too perfect to render it at all probably the work of one cycle. His two-cycle theory implied that there had been no submergence of the area since its first uplift, so that the whole of the vast succeeding period was available for ' adaptation for structure.' This view, however, ignored the existence of the early Pliocene Lenham Beds, of which relics existed on the crest of the Kentish Downs between Maidstone and the coast. First described by Prestwich in 1857, they had been fully dealt with by Clement Reid five years before Davis wrote. Their fauna was shown to comprise sixty-seven species of mollusca and Reid concluded that the depth of the sea was about 40 fathoms.

During the present century the further attack on the problems at issue has followed two converging lines concerned respectively with the relations of the drainage to structure and the former extension of the Lenham Beds sea. The first aspect was taken up by H. Bury in 1910 in a paper to which, even now, full justice has hardly been done. The absence of any adequate published discussion on his paper, printed by the Geological Society, indicates how far into the background the Weald and its problems had fallen at that date. The essence of Bury's argument, applied by him first in the western Weald, is that the transverse or consequent rivers cross the lines of powerful minor anticlines and



Some Elements in the Drainage Pattern of Southern England. 1. Existing streams. 2. Presumed courses of consequent streams of Mid-Tertiary cycle. 3. Presumed courses of consequent streams of Late Tertiary cycle. 4. Streams adjusted to structure. 5. Inferred margin of pliocene land area.

could not possibly have assumed their present courses until the anticlinal crests had been planed away. This is conspicuously true of the Wey and of all the Sussex rivers. It is, indeed, in this connexion that the common mis-representations of the Weald in simple sections need radical correction. We must note the presence of strong longitudinal folds, such, e.g., as the Peasemarsh anticline transected by the Wey south of Guildford and the Greenhurst anticline and its continuations in Sussex which is crossed by all the consequent streams draining to the south coast. It is idle to seek to dismiss these folds as feeble structural ripples ; they are sharp flexures which in the 'initial' Wealden terrain must have formed anticlinal water-partings between synclinal valleys. If there had been no marine interruption of the work of sculpture, this essentially longitudinal drainage system would have survived, not necessarily unmodified, in the present landscapes. Later D. L. Linton showed that exactly similar conditions obtained in Hampshire and Wiltshire ; the initial drainage accordant with the folding must have been entirely unlike the present drainage which transects anticlines more frequently and consistently than can be due to coincidence. The argument from geomorphology thus calls insistently for marine planation antecedent to the birth of the present drainage system.

Meanwhile the stratigraphical evidence of the supposed marine trespass came steadily to hand. In 1904, Stebbing discovered the casts of fossil shells in the sands at Netley Heath and though only generic determination was possible, this indicated the probable extension of the Lenham Beds into Surrey. Even more important was the demonstration by G. M. Davies that the Lenham sands yielded a highly characteristic suite of heavy detrital minerals by which they could be readily distinguished from Eocene sands. With the ground thus cleared, work by H. Bury, George Barrow, S. W. Wooldridge and A. W. Groves proved that the beds were of widespread occurrence on both sides of the London Basin. It was further evident that they rested on a well-marked wave-cut platform cut in the Chalk and sometimes backed by rising ground marking the margin of the contemporary land. Highly significant, too, is the fact that this platform maintains a very consistent height of about 600 ft. throughout, indicating a complete absence of later warping over a large part of South East England.

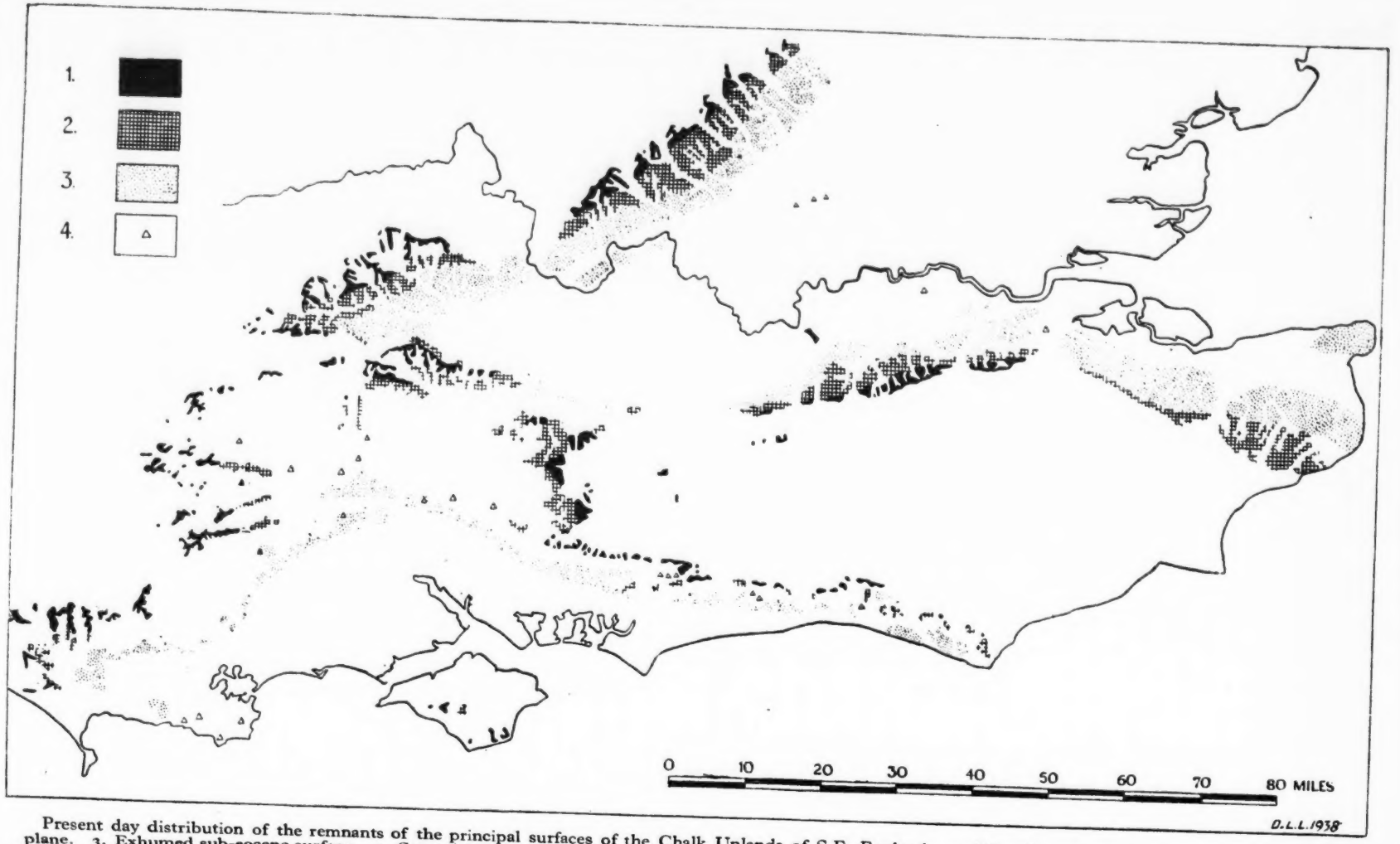
As regards the age of the deposits and the associated planation further evidence has come to light. In 1926, better preserved mollusca were obtained at Netley Heath indicating a Red Crag rather than a Lenhamian (Diestian) age, and a similar age is indicated by the fauna obtained from a relict block of ferruginous sandstone from the Rothamsted Estate in Hertfordshire. This momentarily served to confuse the issue but in reality it in no sense does so. The high-level Pliocene deposits of the North Downs and the Chiltern Hills are parts of a formation, unitary in lithological type and physiographic relations. Prior to 1926 the only fauna with which they could be associated was that of the Lenham Beds of Kent. It now seems probable that all the deposits on or west of the meridian of London are of Red Crag age and one envisages a transgressing sea of which the deposits are earlier in the east than in the west of the region. The later north-eastward retreat of the Pliocene sea is well-evidenced. It should occasion no surprise that we find some evidence of its earlier westward advance.

It is now clear that wherever the sheet of marine Pliocene deposits extends, the drainage is necessarily superimposed, having started its life on the Pliocene cover with the first uplift of the sea-floor. Anticlinal transections are hence readily accounted for. This argument has been used by S. W. Wooldridge and D. L. Linton in seeking to define the extent of the Pliocene trespass in areas where the stratigraphical evidence at present fails. In the Weald it appears certain that all areas exceeding an elevation of about 700 ft. were unsubmerged ; here we have surviving areas of the Mid-Tertiary peneplain inferred by W. M. Davis. Below this level the sea may have extended widely, and though parts of the Pliocene coastline can be traced in the North Downs, it is open to question whether a single large island (see map opposite) or an archepelago of smaller islands remained over the Central Weald. Particularly notable is the fact that the drainage of the Central Weald retains a strongly longitudinal character, which can be regarded as a legacy of its original form.

In sum, therefore, it appears, as is so often the case, that both schools of earlier contestants had part of the truth. There was, indeed, an earlier cycle of erosion culminating in a peneplain, as Davis supposed, but a Pliocene sea advanced over this surface, obliterating the earlier drainage, completing the planation, and covering it with a veneer of sand and shingle. Within the limits of its trespass Ramsay, Topley, Bury and their successors were right ; the hill-top plain of the Weald is there essentially a plain of marine denudation and the drainage has been superimposed from a Pliocene cover.

These earlier episodes constitute, as it were, the pre-history of the physical landscape of the Weald. They concern essentially the evolution of the vanished surface above the hill-tops and are only to be reconstructed by

3. Presumed courses of consequent streams of Late Tertiary cycle. 4. Streams adjusted to structure. 5. Inferred margin of Pliocene land area.



Present day distribution of the remnants of the principal surfaces of the Chalk Uplands of S.E. England. 1. Mio-pliocene peneplane. 2. Pliocene marine plane. 3. Exhumed sub-eocene surface. 4. Summits rising to the level of the marine plane.

indirect reasoning. The general processes by which the existing landscape has been sculptured from the uplifted plain have been well understood since the middle of the nineteenth century, but recent years have seen the beginning of more specialized investigation designed to trace the stages of uplift and sculpture. This has comprised work upon the longitudinal profiles of the rivers which show breaks of slope corresponding to the several stages reached by waves of headward erosion, initiated at the coast by ' uplift,' or more probably, periodic drops of sea-level. The pioneer work was done on the River Mole by a team of the Weald Research Committee which owed much to the stimulus and direction of J. F. N. Green. The profiles of the Sussex rivers have since been worked out. Parallel work has proceeded on the ' platforms ' of the area marking the longer pauses in uplift during which the rivers produced wide valley-plains by lateral corrasion. Of these the most conspicuous is the 200 ft. platform, traceable throughout the area and, judging from parallel evidence north of the Thames, formed before the main glaciation of Southern England. This feature, together with the terraces and raised beaches of Sussex, offer the outline of a Pleistocene chronology of the area of which the details remain to be worked out. In quite another context, Pleistocene times have provided material for research and controversy in the Weald. Though land-ice was absent from the area, it lay well within the periglacial zone and must have certainly been subject to the processes classed under the head of ' nivation.' The ' coombe-rock ' of the South Downs and similar accumulations within the Weald, such as are now classed as ' Taele gravels,' attest the magnitude of Pleistocene ' thaw and sludge.' A. J. Bull has further claimed that snow-melt is accountable for the excavation of such spectacular coombes as the Devils Dyke, which occur also at Butser in Hampshire and on the North Downs near Wye. This attractive hypothesis confronts difficulties in the absence of any evidence of the deposition of material thus removed. It runs counter, too, to the ingenious hypothesis of C. C. Fagg who sees the dry valleys of the Chalk as a whole, as a legacy of the secular depression of the water-table produced by recession of the escarpment. It is probable that there are large elements of truth in both these hypotheses, but the conflict between them has not yet been resolved.

We turn now to the field of plant ecology. The juxtaposition of sands, clays and limestones in an area free from any extensive covering by superficial deposits has rendered the Weald a notable area for the study of striking contrasts in soil and sub-soil conditions and in plant communities. No area in the English lowland shows a greater richness and variety in its semi-natural vegetation. We have here the most typical development in Britain of the modified remnants of the European summer deciduous forest, dominated by beech and oak, together with Chalk grassland and scrub, the highly interesting yew and box woods of the Chalk and a wide range of varieties of ' oak-birch-heath ' representing stages in the succession to oak wood on the drier sandy soils. Accordingly the Weald played an important part in the earlier days of British plant ecology as may be seen from the classic ' Types of British Vegetation ' (1911) and its magnificent sequel from the pen of Prof. Tansley ' The British Isles and their Vegetation ' (1939). Yet it is also true to say that the tale of detailed modern work, has, with a few conspicuous exceptions, proved disappointingly meagre. We are without really exact studies of the stages of succession of the oak woods on the clays and we do not even know with precision the western limit of the Hornbeam in the Weald. Whether this limit be significant or not can hardly be decided until it has been determined. The lack, here as elsewhere, has been primary plant survey. There has grown up a tendency to despise or under-rate work of this character, as specialized laboratory investigation has grown. But it is still true, as Drude claimed, that plants may be studied from three points of view, the physiological, the phylogenetic and the geographical and it could be wished that botanists did not so widely ignore the last in their preoccupation with the others. How repaying and informative high-class ecological research in the area can be is amply shown by the work of A. S. Watt in the western part of the South Downs. This has afforded a clear picture of the stages of succession from chalk grassland to beechwood, and has graphically and powerfully demonstrated the validity of the dynamic principle in the study of plant communities, in tracing accurately the course of development and degeneration of the yew woods. A further standard study was made by F. E. Fritsch of the Heath association on Hindhead Common ; despite the increasing emphasis on experimental work, it is probable that there remains scope for further observational work on the Wealden heaths and their derivatives, since they show a fairly wide range of soil and general site conditions, some of which differ appreciably from those on the high country of the Hythe Beds at Hindhead.

If plant ecology on its observational side seems to have lagged a little in the Weald, work on the animal ecology has hardly begun and offers a rich field for future work.

Present day distribution of the remnants of the principal surfaces of the Chalk Uplands of S.E. England. 1. Mio-pliocene peneplane. 2. Pliocene marine plane. 3. Exhumed sub-eocene surface. 4. Summits rising to the level of the marine plane.

As a human environment the Weald has yielded a complex and significant story from the earliest times to the present. Whether the particular investigations fall within the compass of archaeology, historical geography, or what some have termed social geography, the Weald as a region retains its individuality throughout, and the geographer must necessarily see it as a landscape developing under successive stages of occupancy.

The truly Wealden area within the Chalk ring, expectably enough, has contributed little to our knowledge of Palaeolithic Man and his implements, if we except the outstanding importance of *Eoanthropus dawsoni* —the Piltdown Man. This discovery is sufficient to invest with interest even the thin and unprepossessing relics of terrace gravels which occur above the valley floors of the Central Weald. By contrast, the Weald has made a large contribution to our knowledge and understanding of Mesolithic Man in Britain, for J. G. D. Clark's study records more than a score of sites with the characteristic miniature flint implements ; they are concentrated in notable degree on the sandy areas which, in the relatively dry climate then prevailing, may well have carried light woods or brushwood rich in game. There follows in the sequence of the story the brilliant series of researches by what may justly be called the ' Sussex School ' of archaeology. Dr. Cecil Curwen's books on Pre-historic Sussex (1930) and its more detailed successor ' The Archaeology of Sussex (1937) have proved not only popular in the best sense, but are striking and scholarly summaries of important chapters of British archaeology. From here as much as anywhere in Britain has come the light which has placed the Neolithic period in correct focus, not as a vast vaguely apprehended period of time, without clear structure or sequence but a short period, (circa 2500–2000 B.C.) which marks the veritable dawn of civilization in the area. The classic investigations of the Whitehawk camp at Brighton and of the older hill-top site at the Trundle, together with the patient unravelling of the story of the flint mines, brings into clear relief a picture of the first pastoral immigrants, probably also, in small degree, cultivators of the soil. Sussex has also yielded a series of notable records of the Beaker period of the early Bronze Age and its sequel in the Middle Bronze Age. Even more important is the carefully gathered evidence of the coming of ' Celtic agriculture ' in the late Bronze Age and of the hill-top towns of the succeeding Iron Age, such as the Caburn, Cissbury and the Trundle, and the strong suggestion that with the coming of the last of the Iron Age waves, the Belgic people, the Trundle settlement moved to Chichester to become, the 'new city of the plain,' even before the advent of the Romans.

The Wealden tracts of Kent and Surrey can boast no such full and detailed records ; indeed for the whole duration of pre-history, Downs and Weald are in large measure lands apart and the true south country of the Channel coast appears as effectively insulated from the Thames valley by the Wealden waste. There is no need to exaggerate the degree of separation. Cyril Fox's map showing the massed Bronze Age evidence suggests the presence of an appreciable population in parts of the Weald and of some measure of cross-Wealden traffic. In the succeeding Iron Age there is evidence of contemporary working of the Wealden iron ores and two sites, respectively at Kirdford and Saxonbury, have been interpreted as fortified mining camps.

For the period of the Roman occupation the evidence is naturally much fuller and, in particular, most interesting and important work has been done on the Roman roads. The earlier work of Belloc (1913) and W. H. Grant (1922) and the more detailed survey of Winbolt (1936), went far to reconstruct the line of Stane Street from Chichester to London and this route for long appeared as the only trans-Wealden link in the Roman road pattern. More recently the careful researches of I. D. Margery have completely changed this picture. He has been able to trace in detail the ' London-Brighton Way ' and, the ' London-Lewes Way ' and the course of the road southwards from Maidstone towards Hastings. He has distinguished, too, a number of lesser tracks, both longitudinal and transverse, closely related to the geology and topography of the country and affording at least the skeleton pattern of the human geography of the period.

The earlier stages of Anglo-Saxon settlement are readily traceable in Kent and Sussex in terms of the distribution of pagan burial grounds and place-names. While place-names of early type are not entirely lacking in the central parts of the Weald, the greater part of the earlier English settlement was certainly confined to the fringes of the area ; the great axial tract of forest remained a very real barrier isolating the kingdom of Sussex. A notable contribution to the study of Wealden settlement was made by J. E. A. Joliffe (1933), who found considerable common elements in settlement type, manorial structure and custom throughout the whole of the early settled tracts of the Weald, and concluded that ' the first phase of the English invasion was a general settlement of England south of the Thames, as far west as the Hampshire Avon by a homogenous people.' This view requires closer scrutiny than it has yet

received and is open to criticism in various respects.

If we exclude the features dating from the railway age, the settlement pattern of the Weald as a whole—its village geography, presents remarkable features of regularity and symmetry. At the Brighton meeting of 1872 Topley contributed to the Anthropological Section his paper ' On the relations of the Parish Boundaries in the South-east of England to great Physical Features', noting the scarp-foot villages of the Chalk and their strip parishes ascending the escarpments, and the second line of settlements on the Lower Greensand, with parishes extending into the Weald. He developed his general themes under the heading ' The geological distribution of Population and Disease ' in the last chapter of his ' Weald Memoir.' A former President of the Association, the late Prof. W. W. Watts, remarked on more than one occasion that Topley's ' Weald,' in the hands of one man, Sir Halford Mackinder, contributed more than any other work to the revival of British Geography. It must certainly prove striking to the geographers of this generation to find a geologist, Topley, as the pioneer of their present methods, contributing the results to the Anthropological Section. Nothing whatever of local character figured in the programme of the Geographical Section at the first Brighton meeting and a comparison with the proceedings at the recent meeting enforces the contrast. The Section seems to have learned in the years between the truth of the Chestertonian dictum that, ' To make a thing real, you must make it local.' Though British geographers have yet to produce their own detailed regional description of the Weald, a great deal of contributary work has been done. Hall and Russell's ' Agriculture and Soils of Kent, Surrey and Sussex ' was much more than a technical agricultural monograph ; it is a luminous account of the region as seen by the geographer's eye and embodies one of the earliest applications of the geographer's flexible and powerful tool ' unit dot mapping.' The further development of the purely pedological aspects of this study is represented by the application of the principles of the ' New Jersey classification,' introduced to this country by Linwood Lee, by Bane and Gethin Jones in their study of the fruit-growing soils of the Kentish Lower Greensand, as well as by the work of S. G. Brade-Birks and B. S. Furneaux of Wye College. The more general geographical purview seen as ' regional survey ' is well illustrated by the notable work carried out by the Croydon Natural History Society under the inspiration of C. C. Fagg. The integrated synoptic view of ' natural ' and human phenomena, which modern geography exists to maintain and to further, still finds rather a tepid welcome in the ranks of British Science ; it is regarded as something less than ' science,' useful perhaps as an educational method, but incapable of valid discovery. A review of the progress of our knowledge of the Weald at least serves to indicate how false is such a view and how incomplete is the picture presented by the specialist sciences until the separate strands are reviewed as constituents of an over-all pattern.

This brief account, necessarily incomplete may at least serve to show how much the Weald has contributed to the development of the field sciences. It still offers a rich field both for large scale organized research and for the work of the true scientific amateur without whose full and untramelled enquiries British science would have been incomparably the poorer. It is not too much to claim that the record of Wealden research throws significant light on the motives and methods of men of science and the source of their inspiration. There has been much emphasis of late on what may be called the ' practical ' origins of science as a response to human needs. There is a large element of truth in this view, yet it tends, if not to overlook, at least to belittle the patient curiosity of the isolated observer and the existence of a scientific spirit which ' bloweth where it listeth ' concerned, in a currently unpopular phrase, with ' truth for its own sake ' and unconcerned in the first instance with such practical application as may afterwards arise.

Both these aspects of the scientific views are illustrated in the story of Wealden research. One school may triumphantly claim that the first significant observations on the surface geology of the Weald are to be found in the County reports of the Board of Agriculture late in the eighteenth century. Yet Gilbert White's ' Natural History of Selborne ' fairly and fitly represents the other approach, and in this case at least, the more important one. The stimulus of mineral exploitation has contributed much to our knowledge of the structure of the Weald, but work on its geomorphology, plant ecology and archaeology has stemmed from no such root, yet it contributes as much to our growing knowledge of man and his environment. The report of the committee of National Parks commends for conservation large parts of the Wealden area, notably the South Downs and Forest Ridges, the Hindhead-Blackdown country, and Dungeness. These need protection not only on grounds of amenity and recreation but because they are essential field laboratories for British scientists and will continue to repay study both as a source of ' pure ' knowledge and the breeding ground of materially beneficent applications.

THE PHYSIOLOGY OF LACTATION

REPORT OF A SYMPOSIUM

BY

DR. K. L. BLAXTER

AT the Brighton meeting of the Association a Symposium in which both Section I (Physiology), and Section M (Agriculture) took part was held under the Chairmanship of Professor H. Hartridge, F.R.S. Five papers were presented and these were followed by a short discussion in which both the physiological aspects and the medical and agricultural implications of the papers were discussed.

The Symposium was opened by Professor H. D. Kay, C.B.E., F.R.S., Director of the National Institute for Research in Dairying, Reading, with a paper entitled 'Some Aspects of the Biochemistry of Milk Secretion,' which appraised the general importance of lactation as a physiological function and its sociological significance, and also described some of the problems of mammary gland function under examination by workers at Reading and at the Agricultural Research Council's Field Station at Compton, Berkshire.

Professor Kay emphasised that knowledge of the physiology of lactation was still meagre, despite considerable progress during the past 15 years. This is undoubtedly partly due to the experimental difficulties encountered in dealing with a function limited to only a short period of the animal's life, and to those difficulties of technique, encountered both in the quantitative collection of the secretion in small animals, and in the investigation of the minute anatomy, cytology and biochemistry of the lactating gland. That the subject is of great economic importance to the agricultural industry is ovibous, but its medical and social importance is also very considerable. The lower incidence of breast feeding and the larger numbers of cases of lactation failure in Great Britain is clearly an increasing social danger. Distinct clinical progress has however been reported in the treatment of certain types of threatened failure of lactation in women.

Dealing with the more recent work Professor Kay described some aspects of the biochemistry of milk secretion. The respiratory quotient (R.Q.) of the intact lactating gland measured by arterio-venous differences in oxygen and carbon dioxide content is always above 1·0 (Bottomley and Folley, 1943), and calculations from the oxygen consumption suggest that the alveolar cells are amongst the most active tissues of the body. In the non-lactating gland the R.Q. is always below 1·0, suggesting that, on the basis of the classical interpretation of the R.Q., during lactation, fat is synthesised from carbohydrate. These *in vivo* experiments have been followed by experiments in which mammary gland slices have been suspended in bicarbonate-Ringer containing glucose (French and Folley, 1948). When the gland was actively lactating the R.Q. was above 1·0; when it was not secreting the R.Q. was well below 1·0.

Professor Kay also referred to the work of Dodd and Foot (1948). These workers have demonstrated the effect of single injections of Oxytocin on the ejection of milk from the bovine udder. It was found that ordinary machine milking removed only from 71–81 per cent. of the total milk and less than 50 per cent. of the total fat already secreted by the alveolar cells and present in the udder. The day following the injection there was a compensatory reduction of yield and of milk fat. It is probable that the day to day variability in the fat percentage of milk is due to this factor.

Professor Kay then dealt in some detail with the galactopoeitic effect of spring grass in relation to the progressive decline in the non-fatty solids content of milk which occurs in the late winter months. Oestrogenic activity has been found in spring grass (Bartlett *et al* 1948) and it is clear that part of the effect of spring grass may be due in fact to the presence of an oestrogen.

Reference was also made to the recent discovery of Mr. J. I. Taylor at the Agricultural Research Council's Field Station that there is a definite correlation between the surface wrinkling of the teats of cows and the incidence of Streptococeus agalactiae infection of the teat surface and udder.

Dr. S. J. Folley of the Department of Lactational Physiology at Shinfield presented a paper on the 'Hormonal and Nervous Factors Influencing Lactation.' Dr. Folley dealt with the three phases of endocrine research, first the older neural physiology which was later supplanted by a phase of entirely endocrine research, making lactational physiology

almost a branch of endocrinology. The modern approach to lactation is a synthesis of both these phases into a joint neuro-hormonal approach. Dr. Folley shortly described the hormonal control of the mammary gland, dealing with its growth, under the influence of oestrogen and progesterone, emphasising the species differences in response and the possible role of the anterior pituitary. He also dealt with the initiation and maintenance of secretion, pointing out the spectacular results which have been obtained by the application of this knowledge to dairy farming practice. The neuro-hormonal control of lactation has so far only been studied in relation to the nervous regulation of the secretion of anterior pituitary hormones and in relation to the expulsion of preformed milk from the gland.

It is evident that the suckling stimulus causes a reflex secretion of the anterior pituitary hormone prolactin. There is growing evidence of nervous control of the anterior pituitary with a centre in the hypothalamus, but the pathway is still incompletely understood. It is clear that this mechanism, however, is of major importance in the initiation and maintenance of milk secretion, and also important indirectly for the preservation of the structural integrity of the gland.

Dr. Folley then discussed the expulsion of milk from the gland with special reference to the cow and goat, pointing out that the greater part of the milk in the udder has to be forced down from the alveoli by an active but unconscious process during milking or suckling. This forceful expulsion only occurs when the teat is stimulated or a conditioned stimulus is applied, and is generally known as the ' let-down ' phenomenon. The mechanism was originally explained on the basis of a purely nervous theory, but such an explanation is untenable for there is no evidence of reflex erection of the udder tissue or of the presence of muscle elements. Recent work has shown that the contraction is due to the reflex secretion by the posterior pituitary of oxytocin and the expulsive force is probably due to the contraction of myo-epithelial cells which form a network around each alveolus.

Dr. Folley pointed out the practical importance of this work in so far that good milking technique must take into account these physiological principles. Complete failure of this neuro-hormonal mechanism means complete lactational failure and habitual incomplete emptying of the gland may well shorten the animal's lactation.

In conclusion, Dr. Folley suggested that investigation of the psychological and emotional factors involved in lactation in the human may result in as significant advances in our knowledge of neuro-hormonal mechanisms in lactation as have been obtained in studies with farm animals.

Mr. K. C. Richardson then presented his paper on ' The Cytology and Anatomy of the Mammary Gland.' Mr. Richardson described in some detail the recent studies he has made of the cytology and anatomy of the mammary gland. His paper was illustrated by many slides. He showed that the milk secreting alveolus is a rather elongated structure and the alveolar epithelial cells show considerable changes in shape and size during various stages of the secretory cycle. He showed that the synthesised milk passed from these cells to the lumen of the alveolus by rupture of the cell membrane. Mr. Richardson then discussed the mechanism of the release of milk from the lumen of the alveolus —the so called ' let down ' phenomenon. Various possible theories appertaining to this problem were discussed in detail. There are no sphincters on the ducts leading from the lobules of alveoli which by relaxation could release the milk from each alveolus. There are no bundles of smooth muscle present in the udder which could contribute to the ' let down ' of milk by their contraction. Mr. Richardson then described the method which he devised for staining the myo-epithelial cells which are intimately connected with each alveolus. This method represents a great advance in the histological techniques used for the study of mammary gland tissue and the announcement was greeted with applause by the audience. These myo-epithelial cells are found between the secretory epithelial cells and the basilar membrane of each alveolus and form a close network around each alveolus. They are recognised in transverse section by their relatively large nuclei. Mr. Richardson showed by means of a series of photomicrographs that these myo-epithelial cells contract and expel the milk from each alveolus, and it is clear that these cells are very intimately concerned with the ejection of the preformed milk from the mammary gland.

Dr. K. L. Blaxter of The Hannah Dairy Research Institute then presented a paper on ' The Practical aspects and implications of the Endocrine Treatment of Dairy Cattle.' He pointed out that the endocrine treatment of dairy cattle on a practical scale is of two types ; first the sporadic treatment of abnormal animals suffering from endocrine dysfunction, and secondly the widespread treatment of thousands of normal animals with the sole object of increasing their productivity. Such widespread treatment of large numbers of normal animals presupposes a large supply of endocrine preparations, and for this reason synthetic sources of hormones have the greatest potential use. Synthetic

oestrogens and iodinated proteins which contain thyroxine are products which have been used for increasing productivity on a fairly large scale.

Dr. Blaxter described the early experiments at Reading and subsequent large scale experiments conducted by the Agricultural Research Council in which virgin heifers and barren dry cows were successfully brought into lactation by the implantation of tablets beneath the skin. Unfortunately as far as practical application is concerned, the response is too highly variable and a number of animals fail to respond at all. Furthermore, oestrogen treated animals develop nymphomania and, under the strain of persistent coital mimicry, pelvic fractures occur. In fact, in one experimental series, 20 per cent. of the individual experiments culminated in pelvic fracture.

The hormone thyroxine can be synthesised very simply by the iodination of casein. When such iodinated proteins are fed to cows increases in yield of up to 50 per cent may be obtained. This response is approximately proportional to dosage over quite a wide range. The cows simultaneously become mildly hyperthyroid, and are then comparable to humans suffering from Graves' disease. For this reason large doses appear impracticable.

Dr. Blaxter then discussed in some detail the points which have to be considered before iodinated casein treatment of dairy cows is a practical possibility. The milk produced has been shown to be nutritionally adequate and all evidence shows that the thyroid hormone does not pass the epithelium of the mammary gland. The process is economically sound, to the farmer. Unfortunately the margin of safety between a dose sufficient to give a substantial rise in milk production and one which causes a breakdown of the cow after a few weeks treatment is very small, and the risk of overdosage by accident or through misinformation on commercial farms is very considerable. Nothing is yet known of the effect of continued treatment with iodinated casein on the future productivity, reproductive performance or span of life of the cow and such information is essential prior to any widespread application of this method of increasing milk yields.

Dr. Blaxter emphasised that any widespread use of iodinated protein must be related to established methods of live stock improvement. Where poor herd management, cattle disease and inadequate nutrition limit milk production, iodinated protein treatment is clearly not a general method of improvement, and treatment of animals on farms where such factors limit production, results in less than half the increase in yield obtained on farms where the cows are well fed and cared for and free from disease.

Mr. F. W. Gairns of the Institute of Physiology, University of Glasgow then presented a paper on ' The Innervation of the Human quiescent Nipple.'

Mr. Gairns reviewed the literature relative to the innervation of the nipple and the presence and location of end organs. The recent investigations at Glasgow largely based on mastectomy material were then reported. The human nipple is abundantly supplied with nerve fibres from a number of nerve branches which enter the nipple through the basal muscular layer, in fact innervation is so considerable that this organ can be considered one of the most highly innervated regions of the body. Somatic nerve-end formations are present in profusion and are of several different types. A systematic study of these end-organs has been made and a classification attempted.

Sub-epithelial nerve endings on the external skin surface are few, and are mostly of the loose open network type. Endings around the duct mouths are very common and have been classified into seven main types. Endings are also very common in the myo-elastic tissue and the connective tissue septa between the myo-elastic bundles, and again are of several different types. Although a very careful search was made thorughout the whole series of nipples no Meisner corpuscles were found although their presence has been reported by previous workers. The various types of nerve ending in varying situations were illustrated by a series of slides.

Mr. Gairns then dealt briefly with the nervous mechanism of erection of the nipple in response to the suckling stimulus.

The discussion, which followed these papers, had, unfortunately, to be curtailed. In the short time available, however, many subjects were discussed :—the importance of capillarity in the small ducts leading from the alveoli in the ' let down ' phenomenon; methods of staining myo-epithelial cells; mastitis in dairy cows and the effect of inorganic iodides on milk secretion.

PROBLEMS OF OLD AGE

Report of a Symposium

The medical, social and economic problems created by a rapidly ageing population were the subject of a symposium at a joint meeting of the Sections of Physiology and Psychology on September 10, 1948, during the Annual Meeting of the Association. The following report of the session gives the opening contribution by Sir Ernest Rock Carling and the substance of the other main contributions.

The "60–65" Convention

by

Sir Ernest Rock Carling

It is gratifying to one whose attention has recently been turned to the problem of the elderly, to find physiologists and psychologists interested, for it is their help that now is needed. There is ample room for research both fundamental and applied, by physiologists and psychologists.

Healthy and independent 'old people' outnumber the ailing and decrepit by more than thirty to one; say six and a half million to about a hundred and fifty thousand. Problems connected with the sick and dependent fall to be solved by the statutory authorities, with the help of voluntary bodies. The great majority of the elderly share the same difficulties and troubles that afflict the whole population but the burden weighs a little harder on them. The problems are primarily biological, i.e. physiological, psychological and ultimately pathological. These are complicated by sociological and economic considerations, but since men and women desire to end their days in circumstances comparable with those to which they have been accustomed during their most active life, and since pensions, and nowadays the dividends on savings, no longer suffice to provide such a standard, the most pressing problem for those reaching the recognised age for relinquishing their jobs is—'At what point must I, in fact, abandon the activity by which I earn enough to preserve my standard of living'?

There is a convention that between 60 and 65 the process of ageing has reached a point beyond which useful work can seldom be expected. A consensus of opinion must have had some basis in recurrent experience, but times have greatly changed. Is it reasonable, in the face of those changes, to accept a convention for which there is no warrant in ascertained fact? At least we are entitled to challenge the claim that any particular age for statutory pensioning or retirement is based on proven investigation. The choice was dictated on sociological not biological grounds. With a changed economic bias the time has come for the elderly to revolt. Who can prove, when more than a million are in insurable occupations, that those of 60 or 65 are unfit for further work? Until it be proven, let us maintain that it is an error, promulgated on fallacious grounds which few have hitherto taken the trouble to expose.

In every branch of human endeavour history affords examples of exceptional accomplishment at an advanced age, but they *are* exceptional. It is a truism that chronological age is no guide to capacity in the individual, but what we want to know is, how far the increased expectation of life that has accrued in the last fifty years has extended working capacity. Are the two commensurate?

A female baby born in 1948 can look for almost 20 years longer life-span than one born in 1898, but the woman of 60 today has only a matter of months more to expect than the woman of 60, fifty years ago. Male babies are rather less fortunate, for their expectation has increased only by 17½ years. Nevertheless a far greater number of both sexes are reaching the sixth and seventh decades, presumably because they have been less subject in early and middle life to diseases which have come largely under control; partly as a result of improved medical care, but mainly because of preventive measures of all kinds in the environment.

Ageing begins at birth. An athlete contending in field events is 'old' at 35. The few exceptions excite interested comment tinged with surprise. What *is* it that is old?' Those who have studied athletic prowess believe that exceptional skill is a function of co-ordination rather than of anatomical—that is mechanical—perfection. Co-ordination is, presumably, a function of physiological perfection, but whether it be dependent upon nervous or biochemical quality, or both, is open to question. Experiment has shown that muscular power diminishes slowly, decade by decade, after

its maximum somewhere between 30 and 35, and very laborious work is not to be expected in later years, though many in fact still continue in such occupations, for instance, as quarrying. After 35 too, there is a depreciation in the resilience of elastic and compressible tissues, as well as in the contractile capacity of muscle. There is less rapid adaptability of the vascular supply and clearance ; and some restriction in the range of response to demands on the respiratory and cardiac mechanisms. Reaction times to stimuli lengthen with the years, but to what precise extent we have insufficient data to state. War experience with healthy young men exposed to extreme ranges of temperature and humidity, at high altitudes and great depths, showed that adaptability diminished at an age well within the category ' youth.' We do not ask men of 40 to run the 100 yards sprint, nor to pilot aircraft in the stratosphere ; we find other jobs for them and other openings for their skill. Is it, or is it not, reasonable then to ask artisans and craftsmen to continue at exactly the same tasks when 50 or 60 or more years old ?

In the air-pilot's case there was a psychological as well as the physical factor to be allowed for. In war, of course, it was part of the stress of combat with an imminent chance of mutilation or death, but in peace, too, the stresses inherent in the job may be too great easily to be borne as the years pass, and there are other psychological hazards arising, not from persistent recurrence of different and unforeseen incidents, but from monotony. There is something deadening in a prolonged unchanging rhythm ; energy needs the stimulus of change ; we ' excite ' a nerve in the laboratory ; we need excitement for lively bodily and mental action. Adaptations of work for the elderly must extend to psychological as well as to physical demands.

There have been few controlled researches into the causes or process of ageing. The considerable literature on the subject is not convincing. We don't know *why* our cartilages and arteries become calcified, nor have we any means of preventing the process. Growth ceases, though the cells of the tissues continue to renew themselves indefinitely. A broken bone puts out callus at eighty very much as at eight. We know very well that the sexual organs, ovaries and testes, gradually cease production of their hormones, with results easily recognisable. We don't know whether an increased life span is accompanied by prolongation of the reproductive period, partly because there is a considerable range of time within which the change is normally completed. Apart from disease we don't know that the function of the pancreas deteriorates merely with the passage of time, though we are familiar with senile glycosuria. Eyesight, of course, becomes modified with the diminished elasticity of the lens and its supports ; dark adaptation is impaired as the years pass, but such defects are susceptible to simple methods of compensation. Colour sense is said to lessen, but it is common to see elderly men still competent to judge the temperature of furnaces and molten metals. Hearing, and the sense of balance with it, deteriorates, but there are many factory conditions in which that is no disadvantage, however greatly it may handicap the managing director at a company meeting. Over the whole range of function we need the help of physiologists to measure such modification as age brings. In war they extended the functional powers of young men to a remarkable extent. By similar study they will certainly be able to suggest the optimum conditions for maximum accomplishment when function has been modified or become restricted by age.

Recent work amongst the almost derelict ' chronic sick ' in our institutions has shown remarkable recuperative powers amongst those thought to be past remedial treatment. Whether it be arthritis, contractures, palsies, or even early mental deterioration (the approach of senility), or cardiac or respiratory inadequacy, a determined effort by interested doctors and devoted nurses and physiotherapists can restore a remarkable degrees of independence and usefulness. One may see a hemiplegic with aphasia learn to write with the left hand and even return to valuable work. They can and do learn new techniques.

If in extremely unfavourable circumstances some concentration of effort can restore lost powers, those powers should never have been lost, and continuance in some occupation demanding such exertion would be, and as all doctors know, *is* sound recommendation for the prolongation of life and the preservation of health and happiness.

It would be senseless to pretend that everybody should or could be kept at work beyond present pensionable age ; all that is suggested is that there is no medical reason why a proportion of the population should be compulsorily retired at 60 or 65, or indeed at any specifically dictated period of years. The numbers of those in insurable occupation working after the pensionable age are so considerable that there is no doubt, given some inducement and suitable conditions, the country could draw upon a proportion of the elderly in the population for productive work.

There is plenty of evidence that in the young, physical handicap even of a severe degree, is no bar to productive work. There is a sheltered workshop in Glasgow where

seriously disabled people work and do their job—a selected one certainly—in less time than do the hands in the parent factory. The special machine shop provided for injured workers of the establishment in a well-known motor car factory, turns out work at almost the economic level by those with fractures, dislocations, wounds, mutilations, burns and so on. Special appliances, adaptation of machines and a deal of encouragement are needed, but the job is accomplished.

There is, therefore, no reason to doubt that the disabilities of age can be offset by intelligent adaptation of industrial conditions. There is, moreover, less psychological impediment with the elderly. Wartime experience proved that the elderly are a good steadying influence in a factory; there was less sickness-absence amongst them as a whole in spite of the fact that individual absences may have been of longer duration, and there was no plea for shorter hours, nor in fact, for a slower tempo, though that was probably due partly to the spirit of emulation stirred in us all by the Prime Minister's clarion call after Dunkirk; and partly perhaps to amour propre.

Given agreement as to monetary reward proportionate to turn out, it might well be biologically sound to ask for shorter hours or less continuous effort from the elderly. In fact, of course, the five day week is already a change in their favour. It was noticeable too that accident proneness as a whole was neither a feature of work by the returned retired, nor was there a greater tendency to accidents later in the working shift amongst the old than the young.

Laziness is at the bottom of much facile acceptance of the dictum ' too old at 40, or 50, or 60.' To remain young one must mix with the young, keep learning from the young, and in exchange, unostentatiously impart the wisdom of *experience*, which no endeavour and no exercise of intelligence can secure for those whose years are few. For experience the flow of time is indispensable.

The well educated man has almost always resources of interest upon which to fall back when he ' retires,' yet if the Civil Servant must retire, why does not the clergyman? If the barrister ceases practice, why does not the judge? None of these lead physically laborious lives and many of them continue sporting activities by no means free from exacting physical effort. It is difficult to resist the impression that the reasons for ceasing professional work, or for abandoning a career in commerce or industrial management, are social and economic rather than a failure of capacity. When the work itself satisfies the desire for a feeling of competence or of power and there is no compulsion to retire, men do continue in their chosen employment, and though some may sometimes carry on too long, others demonstrate their continuing ability for many years after the 60–65 range.

No doubt it is difficult for the elderly to appreciate the changes in themselves. Most men, it seems, can recognise in others the deterioration of powers, of which they are unconscious in themselves. Every man is apt to think of himself as an exception to the rules governing age, and as exempt from the disabilities which accompany grey hairs; but that is no reason why he should not continue in endeavour to the linit of his powers. It is not beyond the wit of man to devise means for revealing to any individual in what respect and for what particular employment his powers have waned. Outside that limitation the persistence of effort and concentration is physiologically and psychologically desirable and rewarding. Sudden cessation of such activity is harmful, sometimes it is fatal.

There remain for consideration the small percentage of the elderly whose health precludes any demand upon them for productive work. There is no denying that in the recent past the indigent elderly have been scurvily treated in most parts of the country. Although in great measure the odious features of the old poor law attitude have disappeared, hatred of the workhouse persists. Since the ' Infirmary ' is still generally part of the ' House,' and opens on ' Union Lane ' it is difficult for the best-intentional Local Authority to throw off the damning inheritance. In big wards the dreary sameness, the depressing vista of long rows of tidy beds, is difficult to eliminate. The roomful of sad old people staring at nothing is painfully recurrent to the experienced visitor. It has become clear that the ' big ' institution must be replaced by small Homes, and that 25 or 30 is the smallest economic number of residents. There should be at least three, and probably four, types of small Home, preferably grouped together on the same site as a Communal Club. If the Club caters for the general population as well as for the elderly (who should have their own quarters in it, but communicating freely with the rest), so much the better. The types of Home correspond with the phases of ageing, and to some lesser extent with the social background of the residents. The advantage of having them grouped is that when in due course, with increasing dependence and failing powers, the old people pass from semi-independence to the need for more than domestic care, and ultimately require active nursing, they may shift their quarters

without the change of friends and nurses that old people dread so fearfully.

It is now the statutory duty of Local Authorities to provide such Homes ; of the National Assistance Board under the Ministry of Insurance to pay to pensioners the wherewithal to purchase their accommodation, and of the National Health Service to ensure them home nursing, medical attention and domestic help. The task is enormous, for some two or three thousand such Homes are needed. Local Authorities have power to contract with, subsidise, or contribute to Homes run by Voluntary Bodies and have been urged by the Minister to exercise those powers. It is to be hoped they will do so, but just as the ' Workhouse ' stigma hangs about public endeavour in this line, so ' charity ' taints the efforts of private ventures in the minds of some would-be recipients of badly needed help, and still more in the prejudices of some local politicians.

Summary

The elderly form between 13 and 14 per cent. of the population. Less than 3 per cent. of them are sick and dependent. The numbers entering the 6th and 7th decades are rapidly increasing and their economic position is precarious. If possible they should be kept at work, partly because their services are needed, partly because so to work is the best recipe for continued health and happiness.

Recuperative powers continue into late decades. Disability, at any age, is not incompatible with work. Physiologists and Psychologists demonstrated in war that they could extend the powers of the young and devise means for economising effort and facilitating output of effective work. When they turn their attention to the methods necessary for adapting the altered powers and modified functions of the elderly to work they have hitherto done, or adapting the conditions of work to the capacity of elderly workers and devising means for teaching which are adapted to the modes of learning of the elderly, they will serve the best interests of the senior generation and provide a new reservoir of productive power for the nation.

The Medical Care and Rehabilitation of Elderly People

by

Dr. Marjory Warren

Dr. Warren, Deputy Medical Director of the West Middlesex County Hospital, said that elderly people had always been looked after by someone with varying degrees of efficiency and comfort but the justification for dealing with the matter at this meeting was its increasing size and importance of the problems involved, and the opportunity for putting forward suggestions for medical reform.

Quoting from *Matters of Life and Death* (H.M.S.O.) Dr. Warren said that between 1901 and 1947 the number of persons of 65 years and over in England and Wales had risen from 4·5 per cent. to 10·6 per cent. of the total population, and those between the ages of 45 and 65 from 14·9 per cent. to 23·6 per cent. It followed that there were more elderly people and fewer to give them assistance and many other factors contributed to the necessity for admission to institutions for conditions which could be, or otherwise would be treated at home.

Dr. Warren said that much had been done during the last few decades to improve the conditions of many sections of people and great advances had been made in preserving life and preventing accidents and crippling diseases : but these advances had so far been largely in the treatment of acute diseases and the results had affected mainly children, adolescents and workers. There was an enormous field of work as yet untouched in research into the causes and methods of treatment of degenerative and malignant diseases, particularly those affecting the elderly.

Over 80 per cent. of the old people admitted to hospital were suffering from pathological, physiological, or psychological conditions which fell under two headings—medical and social. The medical conditions were: degenerative arterial disease, degenerative heart disease, arthritis, malignant diseases, and progressive neurological diseases. The social conditions were lack of hygiene, help, food, and company. A service of gerontology was needed which would integrate medical and social care. In addition to domestic and social care, such a service required three types of accommodation : a geriatric unit based on a general hospital, a long-stay annexe for the truly irremediable, and hostels of various kinds for those reasonably fit who had no suitable home of their own. Medically, all three should be under the same supervision, because the lines between sickness and infirmity, and infirmity and health, became finer with the advance of years. Yet new legislation now divided the authorities for medical treatment and social care of the elderly.

Dr. Warren said that the present position was chaotic and uneconomic. An appalling number of remediable old people were lying at home with inadequate care and no treatment, unable to get a bed in hospital. In hospitals there were elderly ambulant

patients, no longer needing hospital care, for whom no hostel vacancies were available. And in hostels there were to be found sick old people without access to treatment.

Dr. Warren described the work of her own Geriatric Unit, a pioneer unit built up during the previous twelve years. A start was made in 1935 by classifying the 700 patients in a transferred Public Assistance Institution, 200 of whom were then removed as ambulant. The remaining 500 bed-patients, some remediable, some incurable, and others whom sufficient ancillary services could have rehabilitated were divided among various wards, and moved from ward to ward as they improved or deteriorated. Some long-stay accommodation was set aside for those whose investigation and all treatment likely to be of use had been completed without likelihood of further advance.

As the work progressed and developed, all new patients were thoroughly examined, medically and socially, with a view to treatment not only for specific disease but to improve their general condition and independence. Treatment included the creation of as optimistic an atmosphere as was justifiable and possible (the setting of a goal for each patient requiring nice judgment). The out-patient department enabled the Unit to see old people referred from other departments and from general practitioners, and also to follow up their own cases ; this work should be increased, as it would enable more old people to be kept at home during treatment—and such out-patient clinics could with advantage be used to screen infirm patients seeking admission to hostels.

Dr. Warren said that her Unit worked as a team, including medical and nursing personnel, physiotherapist, occupational therapist, dieticians, chiropodist, and medico-social worker, and had easy access to other departments of the hospital such as X-ray and pathology. The early years were full of frustration and slow progress but owing to the accumulation of knowledge gathered during the years of development, and the devotion and loyalty of colleagues, the Unit had produced results of great promise. Of the 500 beds originally occupied by elderly people 300 had been released for other purposes and the waiting list had been halved in the previous fifteen months. During two consecutive years, 1944 and 1945, 40 per cent, of the patients were discharged home or into a Home, 15–20 per cent. were found to be irremediable and 40–45 per cent. died.

In January 1948 there appeared for the first time in the medical press an advertisement for a Geriatrician required in Cornwall. The appointment was followed by others for Exeter, Bristol and Belfast.

Old Age as a Social Problem

by

W. A. Sanderson

Mr. Sanderson, Assistant Secretary (General) of the Nuffield Foundation, spoke of old age as a social problem. He said :

Our old-age problems are part of the larger problem of European population trends, which have social, economic, and strategic implications for western civilisation. Europe, having grown phenomenally in population (and in relation to world population) in the last 300 years, has now reached maturity and faces relative decline. Now it is the non-European populations that are growing fast, with declining death-rates and high birth-rates. North-western Europe—headed by France, once the most populous and now the most ' aged ' nation—has led the process, and is destined to contract relatively to eastern Europe, and in particular to the U.S.S.R. Russia, because of late development, is relatively young ; and this has a possible strategic significance. If present trends continue, another 20 or 25 years will see a decrease of nearly 5,000,000 in the manpower of military age in Europe west of U.S.S.R., and an increase of over 13,000,000 in Russia's military manpower. There is a shift in the balance of manpower from west to east.

The static, perhaps soon declining, populations of western Europe are ageing populations, and their working populations are ageing and declining. This means that for youngsters it is easier to start work, but harder to advance, since there are fewer opportunities at the top. The difficulty of individual advancement encourages solidarity among the workers, accompanied by growing pressure in favour of early retirement—blindly regardless of the fact that the retired have to be maintained from the product of the reduced labour force. The increasing social burden substitutes group responsibility for individual or family responsibility, and the enterprising initiative of an expanding economy is replaced by a longing for the security of an ordered economy. And there is created the ' problem of old age.'

In the United Kingdom the present percentage of old people in the population is double what it was in 1901, and treble what it was in 1881—just a lifetime ago. And it will go on increasing until, in the lifetime of many now living, old people will equal or outnumber the children, and the total proportion of dependants (children and old people) to workers will increase from the present 54 per cent. to 62 per cent. Only

technological progress and increasing productivity will be able to keep pace with this growing social burden.

In a simple economy the process of entering and retiring from work is gradual, and in any case not many survived to any great age (John of Gaunt—'old Gaunt indeed, and gaunt in being old'—was only 58 at his death). With earlier marriages and more prolific child-bearing, the family was a unit of many generations, and children or grandchildren sufficed for the support of ageing parents; almshouses and dole charities catered for some of the few who outlived such support, and the rest had no recourse except to the poor law. (As Richard Jeffries makes clear it was this last Master that Hodge most dreaded.) It was not till 40 years ago that the poverty of old age was accepted as something to be ameliorated by the community; and in 1925 social insurance for old-age pensions was introduced. Pensions at the rate of 10*s.* a week made life easier for over 4,000,000 old people, though even so the amount of concealed poverty which existed was revealed when supplementary pensions were introduced in 1940 and successfully claimed by one and a half million pensioners and half a million pensioner-wives. The present rate of 26*s.* a week (conditional upon retirement) came into force partially in October 1947 and fully on July 5, 1948. As the Rowntree Committee pointed out, the new rates are 40–45 per cent. higher than the amounts assessed by Beveridge as necessary for bare subsistence in 1938, and, at the present cost of living, have at last removed the abject destitution of old age. The other problems of old age remain: the lack of companionship and the sense of outlived usefulness, the need for suitable housing and for accommodation with care for those who require it. But many of these needs, too, cost money and materials, which can be provided only out of a dwindling and ageing labour force.

It is true that the new retirement pensions contain an inducement to postpone retirement, but many doubt whether it will be sufficient to encourage those who are only chronologically old to continue to contribute to the wealth of the community. With the first instalment of retirement pensions in 1947 the proportion remaining on in work fell, from 69 per cent for working men and 59 per cent for working women to 64 per cent. and 54 per cent: if it is too early to judge, it is not too early to be thinking of the effect of the 1946 Act.

The exact numbers of old people needing communal care, to be provided by major local authorities under the National Assistance Act of this year, is not known. But if Dr. Sheldon's exact survey in Wovlerhampton is any guide, the present provision needs to be quadrupled, and the total needing care in England and Wales would number nearly half a million. Fortunately family feeling is still strong enough to give devoted and ungrudging attention to many old people past self-care, and so to relieve the community of a responsibility which it would be impossible to contemplate or fulfil.

If the prospect for Britain, and Europe, appears gloomy, with dwindling manpower and the growing predominance of other cultures, it should be remembered that it was western civilisation which, in its vigorous youth, showed the world how to overcome poverty, famine, and disease and so how to release the brake upon population growth. It has yet to be proved that there is any compulsory connexion between social and animal biology, or that an ageing population means a senile body politic.

Skill and Age

by

A. T. Welford

Mr. Welford, described an experimental approach to the problem of ageing as conducted by a research unit set up by the Nuffield Foundation at the Psychological Laboratory, Cambridge. He stressed at the outset that much of what he had to say applied to middle age, rather than to old age, and pleaded in justification first that to talk about the psychological aspects of *old* age would have to be largely a necessary confession of ignorance, and secondly that changes with age were progressive from birth, that some of the striking features of old age seemed to have their adumbrations very much earlier, and that it was therefore necessary to consider old age not as something apart from the rest of life, but as something very much continuous with what had gone before. He continued:

Our task is to try to discover some of the ways in which later middle aged people in industry can be helped by suitable choice and design of work to maintain their efficiency and thereby their self-respect. Our approach to this problem has, however, been not by *ad hoc* investigations but by an attempt to discover the fundamental ways in which skilled performances change with age in the belief that this kind of study, although slower at yielding tangible and definite results is likely to be more generally rewarding in the long run.

The problem is a complex one. We know that certain physical, including neural, changes come about with age. It is obvious

that with passage of years goes an increasing range and amount of experience. Further we know that men adapt to the demands that their work, social life and so forth make upon them, so that what a man has done in the past, how he has been trained and even perhaps the conditions under which he was brought up may all exert their effects. Perhaps more subtly, a man's performance may be affected by popular opinions such as 'you can't teach an old dog new tricks,' or 'no one's any good for this over 50.' What a man does at any particular time at any particular age will be the result of an interaction between all these factors and the demands of the situation confronting him at the time, and will be backed by a chain of similar interactions extending back to birth or beyond, and it is clear, therefore, that to attempt to understand all the forces which may be shaping his behaviour would commit us to an impossibly long programme of work. That does not, however, preclude a modest beginning in a limited field.

In making this beginning, we have not done what has often been done in psychological work in the past and studied simple sensory thresholds, or such variables as reaction times measured in the classical manner, but have used realistic fairly complex tasks and have attempted to analyse these. It is, after all, complex performances that make up everyday work and recreation. The experiments we have done have not, so far, involved heavy physical work or long continued work, but nevertheless some points of interest seem to have emerged, and we expect shortly to make these the starting point of investigations within industry.

Mr. Welford then described four examples of experiments, two involving perceptuo-motor skill—one relatively easy and one more difficult, and two concerned with the manipulation of data in the solution of problems. The experiments were designed to enable not only measures of total achievement, but also measures of the various parts and aspects of the performances leading to this achievement to be obtained. He continued :

It must be very strongly emphasised that any interpretation of these experimental results must for the present be extremely tentative. The scale on which they have been done so far is quite insufficient for them to be regarded as establishing any proven theory. They must be regarded merely as suggestions for further work. It seems meaningful, however, to think of the tasks used in experiments on skill, both motor and 'mental,' as involving first, the comprehansion or organisation of receptor data, and second the building of some kind of effector response or activity in relation to them. Viewed from such a standpoint our results to date seem to present a picture something like this :

On the effector side, our older groups show relatively little change of achievement, but do display some profound changes in the method of attaining this achievement. In particular there is increased care, and the use of planning and past experience. We do not yet know just how much these changes are in response to deterioration of the bodily mechanism and how much they are due to experience as such—that is to the subjects' having found that some methods of work are more efficient or rewarding than others, but we can say the changes are marked.

On the receptor side there seems to be a clear fall in performance, but this does not seem to be due entirely, or even largely, to deterioration of the sense organs. Rather the locus of the deterioration seems to be in the power to organise a visual field or to comprehend or organise data in a problem.

Some striking changes of this nature appear to begin in the thirties, but this does *not* mean that a man's *overall capacity for achievement* falls off at this age. Indeed it is noteworthy that in almost all the experiments we have done so far the star performers have been men who have turned the half century, some by many years.

Some Economic Implications of an Ageing Population

by

Mrs. Barbara E. Lewis

Mrs. Lewis, of the University of Birmingham, read a paper in which she discussed the employment of older workers. As such employment might become an economic necessity it was necessary to examine it from the point of view of the old people themselves and from the point of view of the employer. Two main questions were : how far were the old people able and willing to work and, from the employer's point of view, was it economic to employ old people in a way that enabled them to make a genuine addition to the national wealth ? The following is a summary of the paper.

The fact that women live longer than men is undoubtedly influenced by the tendency of men to retire with a jolt at a fixed age, while woman suffer no such sharp break since normally they are occupied in housework or helping with grandchildren, often to a great age, which gives them a great incentive to remain active and a sense of being useful and needed. While some men look forward to retirement for the freedom to pursue hobbies and interests, there is

some difference between different social and occupational groups ; men in clerical and lesser managerial professions more often look forward to retirement, while manual workers more frequently complain of boredom in retirement. Yet more men in the lower income groups retire earlier, because there is less of a gap between their earnings and their state pensions. In the middle income groups the desire to retire is offset by the prospect of a great drop in the standard of living, more especially now that superannuation and savings are worth less.

During the war a larger number and a larger proportion of old people than in 1939 came into employment, because abnormal labour-shortage pushed the marginal line of labour just worth employing further into the ranks of the aged. The occupations and industries in which the higher percentage of old people were found in 1948 were : tin, textiles (especially lace), leather trades, clothing, printing and paper, and agriculture. Though some of these trades, are skilled handicrafts suitable for protracted employment, in others the proportion of older workers may reflect only a shortage of younger recruits. The old people available and able for employment fall into three groups : those preferring and intending to work as long as possible ; those failing or tired, who look forward to ceasing work as soon as they are financially able to retire ; and those less definite about retirement, who could be swayed by a pension-scheme offering greater inducements to postpone retirement or by special conditions of work if they continue.

From the employers' point of view, it is generally only when loss of efficiency and the need of transference to lighter work arises that there is formal consideration of an employee's age and capacity. There is no difficulty about retaining skilled craftsmen, even when pace and output fall off ; but the unskilled or semi-skilled factory worker who, especially in heavy trades, may lose efficiency with increasing years, is not so easy to retain, since alternative lighter work may be difficult or impossible to arrange. While firms, large and small, have considerable attachment to their own workers with long service, they have a very different attitude to taking on other firms' old workers. Even where old men could successfully undertake work normally done by women or boys, the trade union is not willing that they should be paid less than the minimum adult man's rate, and this makes old men too expensive to use. And even if two old men could be paid only half a younger man's rate to reach the younger man's output, the costs of production will still be higher, since the administrative costs per worker have to be take into account.

On the other hand older workers have many recommendations : they are normally more conscientious and better timekeepers, have greater respect for rules and the employer's property, and generally mind their jobs more carefully, knowing that other work will be hard to find.

As a consequence of an ageing population, industry will have to adjust itself to a labour force with a higher proportion of older workers. This may involve more mechanisation and the further elimination of heavy exertion, possibly some special conditions for elderly workers, and certainly a considerable amount of research and job-analysis to reveal the types of work most suited to the employment of older workers. The most cheerful feature is that, in encouraging old people to remain as long as possible in employment, the best interest of the nation and the aged coincide.

TECHNIQUE AND ECONOMIC ORGANISATION AMONG PRIMITIVE PEOPLES

EDITED BY
ADRIAN DIGBY

THE following extended summaries are of papers read at a session of Section H at the Annual Meeting of the Association in 1948. The introductory paper by Mr. Digby was followed by illustrative papers by Mr. Jones, Professor Hutton and Dr. Leach. These were necessarily limited to agriculture owing to lack of quantitative data for other industries, but emphasised the close relation between techniques and the general economic organisation of the people employing them.

Dr. Hutton's and Dr. Leach's papers were in sharp contrast in their treatment of analogous material, particular emphasis in one case being on yield per acre and in the other on yield per unit of labour. In the discussions, in which Professor Gordon Childe and Dr. von Furer-Haimendorf took part, emphasis turned largely on the differing views held in the last two papers, though there was general agreement that dry cultivation on hillsides, given a long enough cycle, need not be destructive of soil fertility, and that productivity per unit of labour depended to some extent on rainfall. This concentration on one aspect tended to obscure the broad question of the relation of technique and organisation but enough was said to leave no doubt of the importance of the subject.

THE RELATION BETWEEN TECHNIQUE AND ECONOMIC ORGANISATION AMONG PRIMITIVE PEOPLES AND THE IMPORTANCE OF THE TIME FACTOR

by

ADRIAN DIGBY

FOR many years social anthropology, especially under the leadership of the functional school, and technology have been drifting apart. Sociologists with a welter of closely integrated, and often tangled, data before them have fallen back on specialisation as a remedy for their difficulties and to some extent jettisoned material culture as being of least value for their scheme. Those who deal with material culture, mostly curators of museums whose primary concern is with classification and identification, have specialised more and more in what may be termed the comparative anatomy of artifacts without paying sufficient attention to how they are used and how they work.

We can assume that the activities of a community, non-literate or literate, are fully taken up in satisfying a number of needs which are all necessary parts of the daily life of that community. They may be divided into (1) food, (2) clothing, (3) housing, (4) fuel, (5) social integration for the distribution of the results of labour and for security, and (6) for emotional and intellectual satisfaction including marital ties, religion and relaxation. The relative importance of these six factors will vary partly according to the psychology and aptitude of a tribe, and partly according to their historical background and cultural connections. But whatever their relative importance the growth of one factor in consequence, or in time taken, will be at the expense of other factors. It is therefore of the utmost necessity to pay great attention to technique and time involved in relation to production.

Australian aborigines owe their low standard of material culture in part to the time occupied by hunting and food gathering, which are notoriously slow methods of acquiring sustenance, and since this is the first call on their activities they have less time for other pursuits.

Let us take by contrast the Maya, who, from the time of the old Empire, down to the present day have used a system known as 'Milpa' cultivation, which is only a New World variant of 'jhumming' applied to maize cultivation. A research by Dr. Morris Steggerda has shown that the modern Maya, devoting 190 days a year to the production of maize from a 10 acre milpa plot produces twice as much maize as is required for a normal family of five, and has 175 days available for other activities (2 to 6 of my list of needs). What did they do with the remaining 175 days? In matters of everyday life they built simple wooden dwelling houses, and had developed the ceramic and textile arts to a high degree; their stone tools were

of first class workmanship and, towards the end of the so called New Empire, they became skilful metal workers. On a larger scale they built the remarkable ceremonial centres such as Copan and Tikal, to mention but two examples, with their pyramidal structures requiring vast quantities of labour. Their intellectual advancement can be measured by the truly amazing astronomical and mathematical knowledge displayed in their inscriptions. But the fundamental point is that if more time had been required for food production, the other developments, *beneficial* and *otherwise*, could not have occurred. Similarly, greater or less stress on *any* of the other aspects of their culture would have had a major effect on their cultures as a whole.

Another example of the importance of technique comes from the Apa Tani, about whom Dr. Furer-Haimendorf writes, ' Only by the most intensive and *skilful* working of the available land can the Apa Tanis maintain themselves.' But he adds ' despite the scarcity of land and the lack of animal traction and ploughs they have advanced beyond the stage of subsistence . . . and the balance can be spared for feeding craftsmen and those engaged in social and political leadership, and exported in exchange for luxury articles.

Similar considerations apply to other productive occupations, but the data are even scantier. In West Africa there are two types of loom—a wide one, kept in tension by a broad strap which is used by the women, and on the other the narrow frame loom worked with pedal operated heddles worked by men, and weaving a cloth not more than four inches wide. The former requires a very long needle-like shuttle and long slow movements of the arm, while the working of the latter is a very rapid succession of short movements. We know little about the amount of cloth measured in square feet per man hour, what proportion of the daily life is devoted to weaving by either sex or even how much cloth is produced. Whatever the origins of the difference, it is difficult to see properly how the two methods of weaving fit into the organisation, without figures for production and man hours involved.

It is interesting to see the effect of new inventions. A new tool by its superiority to existing equipment may create a demand which can only be satisfied by some departure from traditional practice. We have the example before us of the value set on iron nails and hoop iron by the stone-using Polynesians in the early 19th century and the prostitution of their women to the crews of European ships in order to obtain them. Again the greater ease of production may flood the market, and the social prestige attached to possession of articles, formerly scarce will be invalidated; or the new technique may lead to increased trade with other tribes, and a consequent change of activities resulting from the new situation. The total output of a particular article made by a new method may be restricted by bottle-necks in the supplies of raw materials produced by a less advanced technique. Of course purely economic or social as well as psychological factors will play their part in guiding any changes resulting from modified techniques, but except in rare cases it is unlikely that they can ever invalidate the economic and social changes initiated by new methods.

In the realm of applied anthropology, the need for the study of techniques in relation to the speed of production and social pattern is great. The impact of Western civilisation on primitive communities has two aspects, the social, in which I include all technical and mechanical devices; different means of production; and differing material objects, which add to the wants of a people. Many historical examples suggest that the material tends to be adopted far faster than the social, but the indirect impact of Western civilisation on the social side through material objects is none the less great, and takes the forms, (1) the creation of new demands by the introduction of undreamed of goods; (2) the means of satisfying many demands old as well as new when the right kind of new apparatus is used.

In conclusion I think that the unfortunate centrifugal tendencies of our science, which I mentioned earlier should be remedied if possible, and I believe the link is to be found in the time factor as applied to the study of all productive techniques and the labour forces available. I must plead therefore (and this is the real point of my paper) for the careful study by field workers of technical processes with reference especially to the time and labour taken, and to the *relative time* taken for the satisfaction of the six needs I outlined at the beginning of my paper.

The People of the Big Hoe

by

G. I. Jones

The North Eastern Ibo, called by their neighbours the People of the Big Hoe, number one-third of a million and form a distinct cultural division of the Ibo speaking people. Their cultural differences seem mainly due to a changed social structure, the result of an altered economic system. This economic change was due mainly to the evolution of a superior agricultural technique based on a superior tool—the Big Hoe which gives its name to the people.

The hoe has a larger and more rounded blade and a shorter and heavier handle than the typical Ibo hoe. It is swung high above the head of the user and brought down with considerable force into the ground, and it forms a very effective instrument for shifting the heavy soil of the savannah country in which the people live. The typical Ibo hoe is not, but it was designed for the light sandy soil of the forest areas. The agricultural technique of the Northern and Southern Ibo, probably the most satisfactory for yam growing in such light soiled areas, involves a considerable amount of work in cutlassing jungle, training yam vines, and lifting, cleaning and storing the yams after harvest. It has one obvious bottle-neck—the farmer has to make his yam hills and plant his yams in the few months between the onset of the rains and the period when they come down in earnest. The Big Hoe has enabled the North Eastern Ibo to work the heavier-soiled grasslands where no cutlassing of jungle is required, and where owing to the greater size and better aeration of the yam hills yam vines need not be trained off the ground, and yams, whether seed or mature, can remain in the ground throughout the dry season. The farmer therefore has ample time to make his yam hills and plant his yams, as he can do this throughout the dry season and on through the period of early rains. The chief obstacle to increased production is not labour but land and his social structure has become modified in order to satisfy this demand, and so successfully that the three chief tribes have developed into the most efficient land-grabbing machines East of the Niger, machines which regulated their expansion in keeping with the increase in their population. Beginning a few centuries ago as three village groups covering an area of approximately 25 square miles, they now consist of three large and ten small tribes covering an area of over 2,000 square miles.

Amongst most other Ibos the highest political unit was the village group, a local community averaging some 5,000 souls and composed of a number of villages which managed to live relatively close together without undue friction by zoning themselves around a single centre and each occupying and using only that land which extended in a particular direction from this centre. Their houses were built on that portion of their land near the centre and their farms were cleared on the land beyond. Thus each village group had two zones of land. One of 'Houseland' immediately surrounding the group centre, and beyond this a second zone of farmland. As people only farmed a limited distance from their homes, once all the farmland within a convenient distance of the centre had been taken up further expansion could only be made by founding a new settlement which in due course developed into a separate political unit. For there were no effective institutions for maintaining close contacts with groups outside the houseland zone and the pattern for territorial expansion, while minimising friction between the component villages of a group, was bound sooner or later to bring them into conflict with their nearest neighbours.

The North East Ibo tribes began in the same way as a village group of three related villages, each of which expanded in a given direction. Losing their original unity each developed into a separate political unit (tribe) and in the process modified the typical Ibo pattern by sending their people to settle on their farmland, and by using such residence as a means of holding land seized from the original inhabitants of the country. But they kept to the Ibo pattern of expanding only in a given direction, and they maintained their cohesion by settling only their younger folk on the farmland and keeping the heads of the various lineages in the original villages. So that if one examines the structure of the Iji tribe which to-day consists of over 120,000 people grouped in 12 primary segments (sub-tribes) one finds two original (Mother) village groups, Amague and Abia, the latter derived from the adjacent Ezza tribe. Both of these sent out ten satellite villages (Onuhu) each derived from one of the component villages (maximal lineages) of the mother group, to settle on their extreme boundaries ; and each of these satellite villages developed into a separate sub-tribe, extending its territory from a strip a few miles long to one of twenty miles or more, but never expanding laterally until it had outdistanced the sub-tribes on each side of it. As it expanded it distributed its people over the strip in a chain of small settlements, called Ndiagu, at intervals of a mile or so. The extended families (minimal lineages) which composed the sub-tribes thus became extended in the literal sense, some members residing in the *onuhu* village or in the older Ndiago, others in the newer ones 15 to 20 miles distant. Most of the institutions which made for the Ibo village group unity—Religious (e.g. Yam Festivals and the Ale cult and ancestral grave cult) and Political (e.g. prohibition of homicide and of intra-group warfare) were retained but expanded on a tribal basis. Each Ndiagu for instance looked to their founding settlement as their head, and these in their turn were focused on Amagu village group which preserved the grave of the tribal ancestor and which originated all the important religious festivals.

A Brief Comparison Between the Economics of Dry and of Irrigated Cultivation in the Naga Hills and Some Effects of a Change from the Former to the Latter

by

Professor J. H. Hutton

Mr. Digby assumes that the activities of a primitive community are directed to satisfying six main needs which are competitive. But food production is most important for without it the others do not arise. In proportion however as the necessity for food is satisfied time will be available for the developments of other needs which in turn will compete among themselves for the remaining time and give rise to different patterns of social life.

This theme can be readily illustrated by the comparison of the economies of various Naga and Kuki tribes with similar environment, where many variables are eliminated.

The more important food resources of these tribes include taro, the sweet potato, sago palm, Job's tears and various species of sorghum, millet and rice. The latter perhaps began in Manipur as an irrigated crop introduced from Bengal, but could only be grown by the Angamis by means of elaborate stone-built terraces on the hillside and irrigated by carefully constructed water-courses.

This form of cultivation involves long-term commitments, for the construction of terraces requires much labour, and implies permanent village sites. But, while involving intense initial effort this method greatly reduces long-term effort. The so called Jhum cultivation employed with millet and dry rice involves less initial preparation of permanent value, but demands continuous labour felling trees and weeding, whether new villages are occupied as among the Thado Kuki or whether regular sites are occupied in rotation as among the Garo and Kacha Naga tribes. It is true that when clearing virgin forest or using a clearing rested for 20 years he may get a higher yield, but he rarely has that advantage. The incessant agricultural occupation of the *Jhumia* is well illustrated by the Sema cycle of operations. The women begin in November by cleaning the last year's crop fields for a second sowing (of millet) while the men clear fresh forest for new fields. By February or March they have collected the stubble and trees which are burned. The new fields are sown in April, and the old fields have to be worked until the millet is high. By then the new fields need weeding. Early in July the millet is harvested. Then the cultivators' attention is turned back to the new rice fields which have to be weeded again and again till harvest starts in September, continuing till November.

Obviously the cultivator of jhum land has little respite from the fields. The cultivator of irrigated terraces is in a better position. The Angami, although he may have a little subsidiary jhum land, depends basically on the latter, not exerting himself so much on the former. His irrigated terraces do not require work until March or April when rice seedlings are planted out on dry ground and the terraces are dug over before flooding. Some labour is spent on maintenance of water channels, and transplanting in May and June is heavy. After that the Angami weeds about three times and harvests in October or November, but weeding is easier than on jhum lands. In contrast to the Sema he has three comparatively free months and has a surplus of stored rice.

This contrast has a marked bearing on the life of the tribe. In three months when the jhuming tribes are busy clearing their fields, the Angami, freed from the need of meeting diatetic needs turn their attention to social integration ; Harvest Festival, and Feasts of Merit are more colourful than among the Sema, and ceremonial visits are paid from village to village. The men have more time for wood carving and the women for pot-making and there is a greater air of prosperity than among Sema villages.

A more fundamental advantage accrues to the irrigated cultivators in the form of a greater concentration of population and communal stability, which lead to greater political and military power. On the other hand ' jhumming ' tribes seem to be better integrated for communal effort than the terrace cultivators perhaps because weeding gangs, essential on jhum land, are not needed on terraced land where more could be done individually.

Among the jhumming tribes a certain amount of the specialisation which occurs may be due ot the absence of any leisured period, though other factors may be contributory. This in turn encourages the growth of trade between villages.

In conclusion the change among the Sema, formerly a jhumming tribe whose land was totally inadequate, and rapidly becoming denuded by too rapid cultivation may be quoted. After many difficulties Government introduced terracing and after a number of years a marked change was noticed.

Some Aspects of Dry Rice Cultivation in North Burma and British Borneo

by

Dr. R. E. Leach

In the following paper many of the ethnographic facts approximate to those used by Professor Hutton. An apparent divergence

in the interpretation is not really fundamental. The classification of rice-growing technique into upland or dry rice and lowland or wet rice is unsatisfactory. There are many varieties which do not fall into these two categories. Moreover many peoples are not limited to a single technique.

In colonial territories of south-east Asia the complementary relationship between these different procedures is seldom appreciated by administrations. Dry rice cultivation is frequently condemned as wasteful and inefficient within consideration of the meaning of efficiency in this context, and the problems of labour redistribution are often overlooked in their recommendations.

In terms of the labour calendar, however the fundamental distinction is not between wet and dry cultivation, but depends on methods of preparing the field. The three methods are :—

(a) that in which the seed bed is broken up by fire alone (exclusively dry rice).

(b) that in which the field is prepared by a hoe (wet and dry rice).

(c) that in which the field is prepared by animal drawn plough and harrows (wet and dry rice).

The importance of these distinctions arises from the factors which limit productivity. Assuming for the moment unlimited availability of land, the cultivable area will be limited to the area which a given unit can care for in the busiest season. With dry rice this immediately precedes the time of sowing ; with wet rice it immediately precedes the period of transplanting, that is about two months later. It is on this account that wet and dry techniques can with advantage be practised simultaneously. This busy season is the period when the soil is being broken up by fire, by hoe or by plough as the case may be.

The most nearly satisfactory comparative figures for a family of five are as follows :—

(1) Fei, describing rice growing in Yunnan : $1\frac{1}{3}$ acres by hoe cultivation.

(2) Lindrop, MyitKyina District, Burma : 16 acres by ploughing.

(3) Author's observations, Burma : $2\frac{1}{2}$–3 acres by fire only.

Dry rice cultivation appears more efficient unless the yield per acre of hand-cultivated wet rice is twice as great. But to prevent further erosion a fallow period to allow for the growth of secondary jungle should intervene between clearings. Where space is insufficient for a full twelve-years cycle gradual denudation and loss of fertility will ensue.

In many cases to-day restriction of available land is largely due to European action, the development of rubber plantations, etc.

I believe that hand cultivation of wet rice in terraces gives a poorer return for labour than any other form and is only found where shortage of land overrides all other considerations.

A Kachin village in North Burma illustrates the argument. It cultivated rice in four different ways. These different methods were complementary to one another, rather than alternative. The four methods were as follows :—

(a) by ordinary *taungya* technique ; forest clearings were worked for two years in succession and then abandoned for eight. Fertility was falling as the jungle did not make a complete recovery at each cycle.

(b) by a modification of *taungya* adapted for the cultivation of dry rice on grass downland. This involved the use of hoes but not ploughs ; it was known locally as *hkaibang*.

(c) by wet cultivation in irrigated terraces using animals for ploughing and harrowing.

(d) by wet cultivation in irrigated terraces on steep hillsides using hand labour and hoes only.

The Kachin preferences for different types of cultivation were obvious. Irrigated wet rice with animal traction was recognised as much the most advantageous ; anyone possessing such land was rated a rich man. *Hkaibang* grassland cultivation came next. Ordinary jungle *taungya* was rated rather lower than *hkaibang* in popularity. Most striking however was the low esteem in which wet rice land worked by hand was held. This evaluation was clearly based upon considerations of labour effort rather than of gross yield, since it was fully recognised that a better yield per bushel of seed could generally be expected from any form of wet rice as compared with dry.

Hand-cultivated wet rice side by side with jungle *taungya* is also the general pattern in many parts of British Borneo. It is worth considering the relative advantages and disadvantages of these two methods and their possible influence upon the form of local community organisation.

In the first place, simply in terms of yield per acre there is no great advantage on either side. It is true that wet rice intensively cultivated and manured can be made to produce fantastic yields (up to 150 bushels per acre according to some Chinese authorities), but

the ordinary hill farmer cannot expect anything of that sort. In North Burma the anticipated yield from a wet rice terrace is in the range of 25–40 bushels per acre. The best *taungya* land can also give yields of 40 bushels or over, though under modern eroded conditions this figure may fall to 15 bushels or less. In Borneo yields are lower all round but here again wet rice has no absolute superiority over dry simply on a yield per acre basis.

If it is economically disadvantageous to substitute terraces for good *taungya*, and if it is also true that the prevalence of overworked and eroded *taungya* is largely the outcome of colonial administration, why did the Ifugao, the Angami Nagas and the Lashis choose to undertake terrace construction on a lavish scale before the advent of Europeans? The answer is political. The Kachins have made the greatest success of *taungya* style cultivation. They normally live in small communities of 15 to 25 households which are federated together on a clan basis over a large area. In contrast the hill peoples of North Burma and Assam, whose economy is based mainly on terraced wet rice cultivation live typically in large villages. Most Lashi villages contain over a hundred houses. Angami villages range up to 500 houses apiece. Permanent population concentrations on this scale would be quite unpractical if subsistence were to be based exclusively on *taungya*. The huge size of these Naga villages was in the past correlated directly with military strength, and it is this military factor which seems to me the most reasonable explanation for the existence of terraced rice.

My theme has been that *taungya*-type rice cultivation is not just an archiac residue but has a sensible economic basis which merits more study and attention than it has yet received. The efficiency of rice growing techniques cannot be assessed simply on the basis of yield per acre of land cultivated. Land is only one of the factors of production. One needs also to consider the out-turn per unit of labour. I have stressed that the existing form of community grouping is correlated with the routine of agricultural practice and I have also stressed that many rice growing procedures are complementary to one another rather than strict alternatives. I recognise that the traditional agricultural routine of the rice growing hill-peoples must be reformed, but I suggest that that reform can best be achieved by incorporating complementary subsidiary techniques rather than by outright abolition of the traditional routine.

RICE CULTIVATION CALENDAR, HPALANG VILLAGE, BHAMO DISTRICT, NORTH BURMA

Climate	Month	Taungya	Hkaibang	Wet-hoe	Wet-plough
Dry cool	Jan.				
	Feb.	Felling Fencing			
	Mar.				
Showers					
	Apr.		Clearing Burning		
Dry hot		Burning	Hoeing	Hoeing	
	May		Hoeing	Preparation and sowing of rice nurseries	
Monsoon begins		Sowing		Hoeing	Ploughing
	June		Sowing	Repairs to dykes	
Period of heavy rain				Hoeing	
	July	Weeding		Hoeing	Harrowing
			Weeding	Transplanting of rice from nursery to main field	
	Aug.			Weeding	Weeding
Fair Periods	Sept.				
Monsoon ends	Oct.	Early rice harvest			
Dry cool	Nov.	Late rice harvest			
	Dec.		Harvest	Harvest	Harvest

THE CONTRIBUTION OF INSTRUMENTS TO INDUSTRIAL PROGRESS[1]

BY

SIR EWART SMITH

INTRODUCTION

THE instrument field is already a vast one and it is extending rapidly as the result of advances in physical science on the one side, and the ever-growing demands of industry on the other. Industrial processes are becoming more complex in detail and the size of the unit is continually tending to increase ; in addition there is the demand for higher efficiency, for continuity in operation and for better control of finish and consistency, all of which call for a higher degree of instrumentation. Better instrumentation in turn leads to still wider possibilities of technical progress.

Modern industry is increasingly dependent on instrumentation for its efficiency. In the time available it is impossible to consider this dependence in technical detail. Instead, I should like to touch on some of the underlying factors governing work in this field, and to stress some of the points which I believe should guide our endeavours towards accelerated progress in the future.

Instrumentation in almost all its forms rests basically on physics, and research in this field is already so widespread and effective (not least in Britain), that its importance does not need to be stressed. As an engineer, I should like to pay a profound tribute to our physicist friends and colleagues for all that they have achieved, and I have no doubt that progress in the future will be equally rapid. May it be applied to constructive, rather than destructive ends.

RELATION BETWEEN RESEARCH AND APPLICATION

Instruments, by their very nature, are frequently created to meet specialised research requirements in the laboratory. Almost invariably these laboratory instruments find ultimate application to industrial purposes, although to make them suitable much detailed development may be necessary. Where a new type of instrument has to be specially devised for industrial, as distinct from laboratory application, research work will also have to be carried out in most instances before a satisfactory design can be produced. Thus, there exists a linkage between physical research in its most fundamental forms on the one hand and industrial instrumentation on the other.

Numerous examples of fundamental discoveries or laboratory techniques which now form the basis of industrial instruments readily come to mind, such as :—X-rays, Spectroscopy, Piezo and photo-electric phenomena and pH measurement.

Examples of instruments primarily developed for industrial purposes are :—The whole range of process control instruments, carbon dioxide meters, safety interlocks etc., instruments for measuring thickness from one side of a sheet only.

THE DEVELOPMENT OF INDUSTRIAL INSTRUMENTATION

Instruments can be divided logically into three types according to their degree of service :

(i) Those which assist manual operation and control.
(ii) Those intended to replace human recording or control while achieving substantially the same result.
(iii) Those which give improvements in control impossible by manual operation, either alone or when aided by the type of instruments in the first two categories mentioned above.

The close relation between industrial progress and instrumentation is obvious to all technically trained minds. It may be useful, however, to analyse briefly the various stages in the historical development of industrial instrument work as a background to the consideration of how further progress can best be made. It is suggested that the main steps have been :

1. The application of simple instruments for the measurement of linear dimensions, mass, volume, etc. The adoption of standards, both national and international, for measurements of this kind was, of course, a pre-requisite for effective progress.

[1] Introduction to a discussion on ' Instrumentation and Control,' arranged by Section of Physics, Annual Meeting of the British Association, 1948.

2. The development of specialised indicating instruments for laboratory or industrial purposes, such as instruments for measuring velocity, viscosity, volumetric flow, carbon dioxide content of flue gases etc.

3. The production of recording instruments for such purposes so that a continuous and permanent trace is obtained of changes, usually on a time basis. These release the human eye and brain from work which is often monotonous, and in addition tend to eliminate errors due to human fallibility. They give the further advantage that accurate analysis of operating results is more readily achieved. It is possible to determine changes and trends in a manner which is far more effective than a comparison of discontinuous tabular records obtained from indicating instruments. Examples in this category are deflectional pen and thread recorders, the more recent mechanically operated self balancing potentiometer and the new ' electronic ' self balancing recorders.

4. The continuous measuring type of instrument is in turn used in industrial processes to provide the actuating impulse for automatic mechanisms which will control the processes in question. Typical examples are the speed governor gear on prime movers of all sorts, automatic boiler controls working on draught pressures or steam pressure, and/or on the carbon dioxide content of flue gas, on steam temperature or on steam demand, etc. ; the control of distillation processes ; furnace temperature controllers, etc.

5. The stage has now been reached where automatic control not only eliminates human effort, but can achieve steadier running and far higher efficiency and output than the very best manual control can give. Typical examples are the automatic radar tracking, gun-laying and fuse-setting of anti-aircraft weapons, or the control of thermostatic chambers which have now been devised to work to within $\pm 10^{-3}$ degrees Centigrade for laboratory work. The refinements of physical measurement, often aided by the newly-developed electronic techniques, make possible the design of instruments which will work to ever higher limits of sensitivity. It would appear that automatic controls can be designed to work within limits which approach those set by the accuracy and sensitivity of the actuating impulse instrument.

6. In the past, instruments have been used and designed mainly as supplements to the plants which they serve. The tendency is now to group indicating, recording and controlling instruments in central control rooms in order to reduce the need for human supervision, and to increase the overall efficiency of co-ordination and control. In fact, automatic control techniques are now reaching the point where they are the heart and brain of an industrial process, with the basic implication that to achieve the best results, such a process should be designed round the control as a focus, rather than that the control should be designed and positioned as an adjunct to that process. Industry is now directing strong efforts towards making available the full potential of automatic control in this way.

7. Finally it appears to be a law of industrial progress that, in general, the continuous process, whenever it can be applied, is always able to give better results than batch or discontinuous methods of working. Not only can higher outputs be achieved for a given level of human effort (when allowing for both capital charges and running costs) but a much more uniform product within closer specified limits can also be obtained. This applies to the mechanical side, as in the assembly of motor cars or railway wagons, no less than in process work, such as distillation of all kinds or the casting of metals, etc. Broadly speaking, much of the advantage of the continuous process derives from the fact that it lends itself so well to instrumentation and automatic control.

Factors Governing Future Progress

If this broad analysis can be accepted, it is appropriate to consider what are the factors on which we should concentrate to make the most rapid further advances in industrial efficiency. Some years ago, I ventured to put forward to this Association the definition that

> ' Research is the process of gaining knowledge in a systematic manner by the study of phenomena, or by the examination and correlation of existing data.'

From what has been said above, it will be appreciated that I am a profound believer in fundamental research, but I think that the time has arrived when it is proper to emphasise the importance of work under the second half of this definition. It is also of major importance that existing knowledge should be codified and indexed so that it may be used quickly and effectively by those who have to apply it to practical ends.

As knowledge becomes more and more specialised, there is an ever-growing need for scientific and technical staff to put effort into the co-ordination of the various specialist fields, so that knowledge can be put promptly to industrial use. If we take the chain which links pure research with ultimate industrial application, it is in the intermediate region generally described as ' Development ' that

the most rapid and effective advance can now be made. Development is necessarily a wide and somewhat ambiguous term, but for the purpose of our discussion, I should like to define it as ' the process of bringing knowledge, derived from research, to the state in which it can be applied directly to useful ends.' As an engineer, I should in many cases prefer to use the word ' design ' rather than ' development,' for I believe that design in its true sense, and not merely applied to the production of drawings, is the essential link which should bind together the potentialities of research, the requirements of the user, and the possibilities of fabrication and construction in the industrial field.

For this to be done effectively, the designer must be an applied scientist in the true sense of the term, and it is on this side that we in Great Britain have not made the best of our possibilities. It would not be appropriate here to discuss the whole problem of scientific and technical education, but I would stress the duty which falls on educationalists and industrialists alike to see that a proper proportion of the best brains coming forward from the schools and the universities is trained in the vitally important and supremely interesting work of development and design over the whole industrial field, and by no means least in the particular sphere which we are discussing today. If we have an adequate number of men well trained in basic science, who subsequently turn their attention to design and application work, there can be little doubt that progress will be accelerated, and that the fruits of research will in fact be appreciated and used to the benefit of the community, much more promptly than is normally the case now.

It is inevitable that there should be more and more specialisation, but with it must come increasing attention to the need for linking together specialist knowledge, so that we obtain an effective and integrated overall result. The applied scientists who are required for this purpose should have the widest possible training and experience, not merely during their academic education, but throughout their subsequent industrial experience.

To make effective progress, it is far more important that those concerned should have the right approach than that they should themselves possess a vast fund of detailed knowledge. The universities and technical colleges should aim primarily at turning out men who have been trained to understand basic principles, to be critical and to think for themselves, so that they may properly apply knowledge to the ever-changing problems with which they will be faced in industry. As a corollary, more and more attention must be given to the codification, indexing and dissemination of detailed knowledge in a form suitable for the applied scientist to use. It is of course desirable that students should be taught where to find such knowledge when it is required. Much thought is now being given to this difficult problem by pure and applied scientists all over the world, and it is certainly one which warrants the utmost effort and attenion if the ever-flowing tide of scientific knowledge is to be properly controlled and canalised.

I would enter the strongest possible plea for increased consideration to be given to the development of a common system of technical terms and language ; that is, to the standardisation, as far as possible, of units, of definitions and of methods of presentation.

It will be generally agreed that it would be beneficial if we could have universal basic standards, and it will probably also be agreed that in the fulness of time these are bound to come. Surely, therefore, we should do our best to hasten that time by accepting willingly, rather than grudgingly, any changes which may assist towards this end. In spite of the inevitable dislocation, we must be prepared to alter units or systems to which, individually, we may have long been accustomed. This subject is one which appears worthy of discussion by the British Association, which brings together so many people with widely varying interests, and so provides a natural forum for the general consideration of such matters.[1] This is, of course, quite apart from detailed work on standardisation which is dealt with by the appropriate organisation.

From the standardisation of units and nomenclature, it is an inevitable step to standardisation of material things. In this connection, I should make it clear that I am not advocating standardisation of complete instruments but, in the first instance, the standardisation, for normal working, of the leading dimensions of common components, and of the intervals between different sizes of components. These are the things which, if put on a proper footing, would not only reduce production effort and increase output and assist interchangeability, but also enable detailed design to go forward very much faster, and with far less thought than otherwise.

I would quote as a typical example the recent discussions between U.S.A., Canada and Great Britain on the standardisation of screw threads. In this field, a major measure of tentative agreement has been reached, and

[1] During the 1948 meeting the Engineering Section had a discussion on the merits and demerits of the universal adoption of the metric system. The four main papers were published in *Engineering* during October, 1948.—*Ed.*

it will surely be our duty, and our opportunity, to take whatever steps are reasonably practicable to bring this most desirable aim to fruition. The difficulties which will arise in individual cases are obvious, but the longer we delay facing up to such matters in a realistic and effective manner, the harder to make will such changes ultimately be.

At this stage, no one would wish to suggest, for example, that the mechanism of instrument clocks should be standardised or limited. On the other hand, it is evident that real benefits would accrue in industrial and scientific work if their overall size and fittings were standardised for ease of interchangeability, etc. Possibly, too, the dimensions of instrument cases and charts could be made with advantage in a reasonable range of standard sizes in a logical manner. It is sometimes objected that standardisation cramps initiative and delays progress, but standardisation should be regarded as the crystallisation, for normal usage, of the best current technique, and in this sense it should enable further progress to be made more quickly and effectively than would otherwise be the case. If development shows that a current standard no longer fulfils this condition, it is in fact far easier and cheaper to change a completely standardised article than it is to introduce the improvement to an unorganised series of components or articles in order to bring them up to the new level.

Conclusion

In conclusion I would repeat my assumption that the dependence of industry on instruments is axiomatic. With this in mind I have suggested several means of increasing the contribution of instruments to industrial progress. It is suggested that progress in instrumentation, whether applied to industry or any other field, will result from :

1. The adoption of a progressive and critical outlook, actively seeking change where it is likely to be beneficial, and not waiting till the force of events makes it inevitable to follow the lead which others have given.

2. The training and employment in industry of a much greater number of applied scientists who will have a basic knowledge of scientific principle, and who will be in a position to understand and apply promptly during the design stage the fruits of scientific research.

3. The general adoption of standard basic systems of physical measurement.

4. The development of a greater measure of uniformity in scientific and technical nomenclature and in methods of presentation.

5. Improvement in the codification and indexing of existing knowledge.

6. More rapid progress in the standardisation of basic dimensions and specifications for elementary components, followed by a measure of standardisation of the leading dimensions of particular types of equipment.

7. A better appreciation of the need for conscious search for continuous processes as opposed to batch operation.

8. The design of industrial processes so that instrumentation and control mechanisms are treated as an integral and key part of the work as a whole. For this to be achieved it is necessary to ensure the closest integration and understanding between the Research, the Design and the User sides of work in the instrumentation field.

BIOLOGY IN THE EDUCATIONAL CURRICULUM[1]

FOLLOWING the Dundee meeting of the Association in 1947, the Council appointed a committee to continue the work of a previous committee and to report on the position of biology in the school curriculum. The work of this Committee continues and a report may be expected in due course. In the meantime, at the Brighton meeting of the Association, the Sections of Zoology and Botany devoted one morning to a discussion on biology in the educational curriculum, including the curriculum of schools. The session was opened by Professor H. Graham Cannon, F.R.S., who, a few days previously, had delivered his presidential Address to the Zoology Section on 'Undergraduate Zoology' (*Advancement of Science*, No. 19, p. 194). Part of his contribution is reproduced here. He was followed by Dr. L. M. J. Kramer, Senior Biology Master, City of London School and Mr. H. J. Bonham, Headmaster of Lutterworth Modern School, Rugby, whose contributions are reported here in full. Professor T. M. Harris, F.R.S., presented a interim report of the Committee mentioned above, and the session closed with general discussion.

INTRODUCTION

By Professor H. Graham Cannon, F.R.S.

IN the teaching of biology there are two sharply defined aspects : there is the study of the structure of organisms correlated with their functioning, leading to knowledge of human physiology and the relation of man to the animal and plant kingdom. This may be looked on as a factual aspect while, on the other hand, there is the study of evolution and all that it implies and involves. This may be regarded as a cultural aspect.

To take the factual aspect first. If there is one thing more than any other with which a child is intimately associated it is with its own body. Its body should become its immediate concern, and all school children, whatever other subjects they may study, should be taught to understand in a simple manner its mechanism and structure. But this is far from being the case, for we still live in an age of extraordinary prudery in which it is improper to discuss anatomical and functional details. This is brought out only too clearly when it is realised that there are no words in ordinary use to describe such natural processes as defæcation or micturition, and as regards the parts of the body, there are no names in ordinary use for the external genital organs. Any words there may be are considered completely vulgar. Now a general elementary study of the human body taken as an ordinary subject for study, quite apart from the educative value that the child derives from knowing what happens inside its own body when, say, a meal is taken, or when a schoolboy collapses exhausted after a hundred yards sprint—quite apart from this, the mere fact of taking this sort of study along with his history or his language or his science would make him feel that here is something quite ordinary and not in any way exceptional. He will then feel free to discuss biological things, things about himself, in an open manner, just as he would without hestiation discuss a problem of mechanics or history. In many schools it is the custom to have a visiting teacher, often a doctor, who appears spasmodically to give short courses of lectures to the older students on what is sometimes called 'personal hygiene' ; but this is all wrong. He comes to talk to the students about sex, and that is where the harm is done. Why should sex be singled out like this ? Why separate the gut from the genital system ? We professional biologists do not, and neither do university biological students. It is this separation of the problem of the human body from the other subjects of study that tends to reinforce the Victorian prudery that we have inherited and to retain those awkward complexes resulting from suppressions which are the curse of adolescent education.

Now as regards biology as a cultural subject, this is the aspect that I consider of such value to the student who is to specialise on the Arts side. All syllabuses, whether good or bad, start from the 'lower' or structurally simple and lead up to the 'higher' or complex advanced types. If this evolutionary story is properly dealt with, not as a series of separate steps but rather as a gradual unfolding from simple beginnings of the complex organisations that we see at the top of the tree, then a student derives a new conception of life as a whole. He realises that it is not only animals and plants that have evolved, but also all other things such as food and clothes, houses and motor-cars and,

[1] Report of a joint session of Sections D (Zoology) and K (Botany) at the Annual Meeting of the Association in 1948.

more important still, mental and social activities. Civilisation, in fact, that he sees around him, he realises is something that has gradually evolved and which he has inherited. The effect of this broad outlook on his other subjects cannot be over-estimated. How often is a student at school learning a language made to understand that that language has evolved? Or, worse still, how often is the school-child, working at some narrowly circumscribed period of history for the School Certificate examination, impressed with the fact that history *is* the evolution of mankind?

These, then, are the two main reasons why I consider biology should be a subject taught throughout the school and to all types of children. It is considered proper by all educationists that certain fundamental subjects such as arithmetic and English form an absolutely necessary part of any school curriculum. Has not the time arrived when it is just as important that the school-child, or the adult, for that matter, should know how his own body and his own society work as that he should know how to calculate compound interest or speak the king's English?

The views I have put forward are nothing more than ideal views. So long as schools are tied down and cramped in their style by having to conform to syllabuses of matriculation boards or standards of university scholarships, it is clear that it is not possible to devote the necessary time and teaching man-power to deal with biology as I have indicated. In 'modern' schools, however, where public examinations are not the determining factor in the teaching curriculum, there is some hope that a broad treatment of biology may be possible.

There is another and most important direction in which valuable biological teaching can be carried out, and that is in adult education. What I have said of the value of a biological outlook to the school-child applies *a fortiori* to the adult. But here again, extramural university teaching is largely bound up with the Workers' Educational Association. This excellent educational organisation, however, is hampered by the constitutional custom that the adult students *ask* for whatever classes they feel they want. As a result, adult education has come to be looked on as largely a development of the Faculty of Arts. The grown-ups ask for subjects such as psychology and economics, that naturally appear to them to bear directly upon their own lives. They do not realise that the subjects they choose are, as often as not, far beyond their mental capacity; in fact, as some of us think, they are beyond the capacity of the ordinary undergraduate. If they could be encouraged to study in a simple and broad manner the elements of biology, then a great step forward could be made in education generally.

Some Aspects of Sixth Form Biology

By Dr. L. M. J. Kramer

Part I

The Expansion of Biological Teaching.

Various reports reveal the history of biological work in British schools. In 1928 the British Association reported on 'Animal Biology in the School Curriculum' [1]. A strong case was made for the study of biology, especially of animal biology, which had been neglected. At that time 95 per cent. of the total entries in biological subjects in the School Certificate and Matriculation Examinations were in botany. The scope of biology in Britain was compared unfavourably with that abroad. In 1927, for example, only one in ten grant-aided secondary schools for boys taught biology.

In 1932 the Government issued a report on 'The Education and Supply of Biologists' [2]. It was shown that while the struggle for the recognition of physics and chemistry in schools was being waged, biology was not regarded as indispensable. The subject was considered hard to teach and the supply of competent teachers was inadequate.

After 1930, however, biological teaching spread. More teachers applied for admission to the then Board of Education's short courses in biology, more laboratories were built, and the number of entries for the Higher School Certificate increased. The representative figures in Table I indicate a tenfold increase between 1918 and 1927, and an increase of 56 times between 1918 and 1947.

Table I.—*Total Entries in Biological Subjects in the Oxford and Cambridge Schools Examination Board Higher Certificate* [3]).

1918	1927	1946	1947
14	144	694	786

Dissatisfaction with the Present Position.

Thus biology may be considered to be well established now in the field of school science, and its scope ought therefore to give satisfaction. The truth, on the contrary, is that there is widespread dissatisfaction.

The Norwood report [4], issued in 1943, discussed Sixth Form science in schools, and, while not singling out biology for criticism, did not exclude it. It was stated in Chapter 8 that eminent scientists disliked the rigid specialisation, that teachers deplored the

amount of factual knowledge pupils must learn, that universities said their students were one-sided, with few general interests, and poor in power of self-expression, and that industrialists were dissatisfied with the general, as distinct from the technical, quality of their scientific staffs.

In 1944 The Royal College of Physicians of London, in a ' Report on Medical Education ' [5], condemned school science. For example, on page 9 it was stated that ' specialisation in scientific subjects for vocational or scholarship purposes in the later school years, may not only interfere with ability of self-expression, but may diminish other interests, in say, history or art.'

The Goodenough report [6] on Medical Schools was published in 1944 and was also critical. The standard of training in physics and chemistry, and especially in biology, was said to be low in many schools.

Such serious criticisms indict not only biological and scientific work in schools, but also an important section of secondary education. If the fight for the recognition of biology has been won, the price of victory seems to have been cultural bankruptcy of the pupils.

The Scope of the Present Paper.

It is noteworthy that the unfavourable reports quoted do not support their statements by evidence that an independent observer can appraise. Opinions are given, no doubt on the testimony of many and eminent witnesses ; yet these are subjective opinions and it consequently appears to be important to examine the criticisms in the light of objective evidence that all can sift. The work described here is an effort in that direction.

The data have been drawn mainly from the records of the City of London School, an independent secondary grammar school of 850 boys. The Headmaster has permitted experiences at the school to be cited.

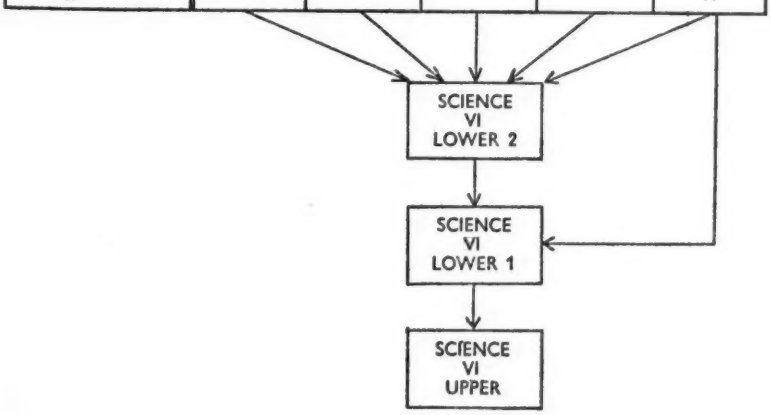
The Effects of Pre-School Certificate Work upon Biological Performance in the Sixth Form.

It was decided to test first whether or not performance in examinations in biology in the Sixth Form was influenced by the work done before the School Certificate examination.

Table II indicates that boys between 13 and 16 years old pass up to the School Certificate stage in 5 streams, which follow different curricula. The Classical and

TABLE II.—*Subjects Taken in School Certificate by Pupils in Each Stream and Movement from Streams into Science VI Form.*

	1 Modern B	2 Classical B	3 Modern A	4 Classical A	5 Science
English	×	×	×	×	×
History		×	×	×	
Geography	×	×			
Latin			×	×	
Greek				×	
French	×	×	×	×	
German			×		×
Mathematics	×	×	×	×	×
General Science	×	×			
Physics					×
Chemistry					×
Biology					×



Modern B streams (columns 1 and 2) have a broad syllabus, stressing neither literary nor scientific studies, but omitting neither. The Classical and Modern A streams concentrate on languages and omit science, except for a little biology for one year, while the Science stream include German and the three science subjects physics, chemistry and biology.

After passing the School Certificate any boy may enter the Science VI Form, subject to there being vacancies. The arrows show that the weaker pupils from the Science stream, and almost all those from the other four streams who choose science, enter a form called Science VI Lower 2, where a predominantly scientific course raises them to a high enough standard to pass into Science VI Lower 1. The stronger Science stream boys enter Science VI Lower 1 immediately after passing the School Certificate. Normally a boy spends one year in each Science VI Form.

Science VI Lower 1 and Upper therefore contain boys with different pre-School Certificate histories, although Science stream pupils are in the majority. Consequently there is an opportunity to compare the performance in the Higher Certificate Examination of boys from the different streams, with a view to discovering whether or not some of the conditions criticised in science sixth forms are associated with a given pre-School Certificate education.

TABLE III.—*Average per cent. Marks Gained in Biological Subjects in Higher Certificate Examination by Boys from Different Streams* (1937 *to* 1947).

	Classical and Modern B Streams.	Classical and Modern A Streams.	Science Stream.
Biology .	48·3	45·3	48·6
Botany .		47·6	44·3
Zoology .		53·3	51·0

STATISTICAL ANALYSIS

	Means Compared.	Value of *t* Found	Value of *t* to be exceeded for significance.
Biology	Sci. with ClA + Mod A.	1·100	2·060
	„ „ ClB + Mod B.	0·009	2·120
	ClA „ ClB + Mod B.	0·722	2·101
Botany	Sci. „ ClA + Mod A.	0·410	2·201
Zoology	„ „ „ „	0·480	2·160

The results, given in Table III, show that the average per cent. marks gained over eleven years in the three biological subjects taken in the Higher Certificate by boys from the various streams differed only slightly. The greatest difference between the means was 3·3 per cent., and no difference was statistically significant. From this evidence it would be legitimate to infer that the type of pre-School Certificate work did not affect the performance in Higher Certificate biology. The full implications, however, are not apparent unless further relevant factors are studied, as set out below.

The Relationship of Classical Education to Scholarships in Science.

Between 1939 and 1947 seven Entrance Scholarships (of all types, including open awards at Oxford and Cambridge and at the Medical Schools of London University) were gained by boys offering biological subjects, together with physics or chemistry. Five of the successful candidates had passed up the Science Stream and two up the Classical A Stream before the School Certificate. Thus the ratio of Science Stream scholarship winners to those from the Classical A Stream was five to two, or 2·5 to 1. But the ratio of the Science Stream boys in the Science VI form to those from all other streams in the same form was 4·1 to 1. That is to say, in proportion to their numbers in the Science VI form, the Science Stream pupils succeeded less often in scholarship examinations involving biology than did the pupils from the Classical A Stream.

Caution is necessary when drawing conclusions from so few results, yet one may ask if any benefits of a pre-School Certificate classical education had become apparent in the stringent test of a scholarship examination, because if that were shown to be so, then clearly the implications for secondary schools could be remarkable. It is therefore important to consider evidence that indicates that the better performance was not necessarily due to the classical training.

For lessons in mathematics boys from all streams were pooled and divided into sets according to mathematical ability and therefore irrespective of stream. By knowing the sets and streams of all the boys one can discover the percentage of boys in each stream who were in the top mathematical set. From Table IV it is seen that there were considerable differences between the streams, the Classical A Stream being richer in mathematical ability at all ages than the Science and Modern A Streams, and very much richer than the Classical and Modern B Streams.

Table V gives information upon the

relation between ability in mathematics, physics and biology. The data for correlating mathematical with biological ability did not lend themselves to the calculations of a correlation coefficient ('r'), so the results are represented graphically. It is shown that as mathematical marks in the Higher Certificate rose, there was a fairly regular rise in the marks of the same boys for physics (Table VA). On the other hand, as mathematical ability rose (as indicated by the pre-School Certificate mathematical sets boys were in), there was no orderly change in the same boys' marks for biology in the Higher Certificate (Table VB).

The bearing of these results upon scholarships may be interpreted as follows: Mathematical distinction, as might be expected, is some index of prowess in physics, but is not necessarily a factor in success in biology. Hence, in a scholarship examination involving physics as well as biology, mathematical ability will be a factor in success. The higher level of mathematical ability of the Classical A Stream thus emerges as a factor in their relatively better scholarship-winning record than that of the other streams.

In harmony with this evidence is the fact that the B Stream boys have not, in the eleven years' results investigated, ever taken botany or zoology in the Higher Certificate examination. They usually took so long to reach the Upper Sixth Form that they were too old to remain in the school, and to reach the required standard. They were able, however, to reach Science VI Lower 1, who took biology in the Higher Certificate. From Table III it can be noted that there are no marks available, for the above reasons, for botany and zoology for the B Stream boys. Table IV indicates that their level of mathematical attainment was very much lower than that of the other streams.

TABLE IV.—*Representative Figures to Show Proportion of Boys in Each Stream who were in Set 1 for Mathematics* (1939 + 1934 + 1947).

	Percentage of Boys in Maths. Set 1.				
	Modern B	Classical B	Modern A	Classical A	Science
3rd Forms (13–14)	1·2	3·7	29·7	44·1	31·0
4th Forms (14–15)	2·9	5·3	30·6	40·7	27·7
5th Forms (15–16)	2·6	1·2	22·8	40·7	27·7
Average for All Forms	2·2	3·4	27·7	41·8	28·8

TABLE VA.—*Relation of Higher Certificate Marks for Physics to those for Mathematics* (1937 *to* 1940).

Maths. Marks.	Average Physics Marks of Same boys.	The lengths of shaded parts are proportional to Physics Marks. 50 100 150 200
150 to 209	118	
210 to 269	164	
270 to 329	149	
330 to 389	169	
390 to 439	181	
440 to 499	202	

TABLE VB.—*Relation of Pre-School Certificate Mathematical Set to Marks for Biology in Higher Certificate* (1937 *to* 1947).

Pre-School Certificate Maths. set.	Average Biology Marks of Same boys.	The lengths of shaded parts are proportional to Biology marks. 50 100 150 200
5 (Lowest)	137	
4	169	
3	150	
2	141	
1 (Highest)	154	

The evidence of the scholarships considered as a whole leads to the conclusion that the streams varied in ability, and that superiority in gaining scholarships was probably due more to the boys' superior ability than to the type of curriculum followed in the years before taking the School Certificate.

Discussion of Part I.

It is desirable at this point to reconsider Table III in the light of the scholarship record and its attendant circumstances. Because of the differences in ability between the streams it might be expected that the performance in biological subjects should reflect those differences. In fact it does do so indirectly for the following reasons : (i) the Classical A Stream boys, with almost no pre-School Certificate experience of science, held their own with the Science Stream pupils, as shown by the figures in Table III. Although the marks for the Classical and Modern A Streams are grouped together in Table III, it should be noted that the Classical A Stream outnumbered the Modern A Stream by 5·5 to 1. The year spent in Science VI Lower 2, while giving a sufficient background to make competition with Science Stream boys possible in Science VI Lower 1, did not give quite enough to enable the Classical A superior ability to make itself very evident. When, however, the Classical pupils have acquired enough experience of biology, their greater ability tells, not only in scholarship-winning, but also in the trend of the zoology and botany marks, which are better than those of the Science Stream, although not enough to be statistically significant.

(ii) The B Stream pupils, in view of their lesser ability, did not reach the standard of zoology and botany taken as principal subjects before they were too old to stay in the school, and this fact tallies with their relatively bad record as winners of scholarships.

In setting these results in perspective it is desirable to view with adequate reserve evidence derived from only one school, however large or representative of one locality, and to beware of generalising prematurely. In such work, moreover, a number of very variable factors may have to be taken into account, and results assessed with regard to differences between personalities and methods of teachers. It may one day be shown, for instance, that the classical education has caused its devotees to be more accurate, or that a Classical Stream boy owes his better results partly to harder work, induced by the knowledge that he has more leeway to make up than has his Science Stream counterpart. Only further critical research could settle these points.

But it is reasonable to hope that the type of investigation described in this paper will yield important information. For example, a preliminary inspection indicates that there is no correlation between biological performance and attainments in English in the Higher Certificate Examination, suggesting a line of enquiry that might bear upon the criticism that science pupils are poor in self-expression. Again, an investigation of the type recently carried out by Houslop and Weeks [7] on the interests of boys could help to determine in what way Sixth Form Science, or its branches, narrows or broadens general interests.

A fruitful field of work seems to lie ahead, and it should be possible to assess objectively the implications of criticisms and of proposed reforms. Without further objective work it would be unwise to assert that all the reasons for existing dissatisfaction are known. Hence it is doubtful if sound remedies can with sincerity be brought forward now.

In view of the abolition of the School and Higher Certificate Examinations after 1950, and their replacement by a School Leaving Certificate, and of impending changes in medical education, there is urgent need for accurate information as a basis for formulating rational future policy.

Part II

Conditions Affecting the Teaching of Biology in Sixth Forms.

A review of the conditions in which Sixth Form biology is carried on may suitably take into account the factors affecting the teacher. Probably his most responsible task is advising boys on the courses they should follow and the examinations they should take. A false judgment may permanently jeopardise a pupil's chances of achieving what he wants. Details of regulations, estimation of chances of success, age and needs differ for every pupil. The teacher of biology must be able to advise on different occupations calling for biological training. A need that might well be met by some appropriate means is to provide schools with recent information about biological careers. At present the biology master has to seek far and wide with the help of his colleague the careers master.

The composition and requirements of the class at the beginning of each school year bear on the teaching techniques that must be selected. A fresh Sixth Form contains pupils of diverse capabilities. All still have a Fifth Form outlook, and an important step to effective work is to assist the class to

glimpse the broader horizons that work in a Sixth Form *can* display. It is particularly necessary to insist upon accuracy and to cultivate practical skill.

At least eight other factors are concerned in planning courses :

(i) the size of the class,
(ii) the number, frequency and duration of lessons,
(iii) the equipment available,
(iv) the provision of specimens, which is nowadays often difficult, especially animal specimens,
(v) the availability of books,
(vi) laboratory assistance (or the lack of it),
(vii) facilities for field work, and
(viii) the syllabuses to be covered, for the class is certain to be mixed, some boys requiring preparation for the First Medical Examination, others for the Higher Certificate, some for the External Intermediate B.Sc. of London University, and some for University Entrance Scholarships.

An Analysis of Question Papers.

Probably most teachers would agree that success or failure in an examination largely depends upon what a candidate writes. An important part of his preperation, therefore, is the acquisition of knowledge and skill to answer the exact points the examiner specifies, within the time allowed for the paper, in good legible English and with suitable illustrations. To do this well under the stress of examination conditions is not easy.

To help candidates as much as possible it is necessary to discover the kind of answer examiners want. Some information about the balance of question papers and the emphasis placed upon various branches of biology can be obtained by classifying questions.

Each of the columns 2 to 8 in Table VI corresponds to one examination; thus columns 2, 5 and 7 refer to the Oxford and Cambridge Schools Examination Board; columns 4, 6 and 8 to the University of London External Intermediate B.Sc. Examination. The numbers in the columns 2 to 8 are percentages, and show the percentage of questions set by each of the examining bodies on various branches of biology during the last five years. For example, opposite Embryology in column 2 one reads 3·3, meaning that of all the questions set during 5 years in the O.C.S.E.B. Higher Certificate biology papers, 3·3 per cent. were on animal embryology. The figures in each column add up to 100. By reading the rows from left to right one can discover the percentage of questions set upon each branch by each body.

Column 9 shows the range of variation; for instance, for questions on invertebrates it is from 3·3 per cent. to 26 per cent. From

TABLE VI.—*Classification of Questions on Biological Subjects Set between* 1942 *and* 1947. (*For Explanation, see Text*) [8].

	Biology.			Botany.		Zoology.			
1	2 O.C. S.E.B. Higher Cert.	3 Lond. First M.B.	4 Lond. Inter. B.Sc.	5 O.C. S.E.B. Higher Cert.	6 Lond. Inter. B.Sc.	7 O.C. S.E.B. Higher Cert.	8 Lond. Inter. B.Sc.	9 Range	10 Author's Time.
Anatomy and Histology of Vertebrates	10·0	26·4	14·9			17·1	39·2	10 to 39	18
Invertebrates	10·0	4·2	3·2			25·7	25·7	3 to 26	20
Embryology	3·3	8·3	6·4			5·7	12·3	3 to 12	2
Animal / Plant } Physiology	20·0	13·9	31·9	26·0	23·4	8·6	14·6	8 to 32	14
Morphology, Anatomy and Histology of Seed Plants	14·4	13·9	8·5	28·1	30·9			9 to 31	22
Families of Seed Plants				5·2	2·1			2 to 5	2
Spore Plants	12·2	9·7	8·5	11·5	29·8			9 to 30	13
Plant / Animal } Ecology	4·4			12·5				4 to 13	0
Genetics	3·3	4·2	4·3	3·1	2·1	7·1	2·9	2 to 7	3
General Biology (e.g. Evolution)	21·1	19·5	22·4	11·5	9·6	32·9	5·3	5 to 33	7
Applied Biology	1·1			2·1	2·1			1 to 2	0

the evidence given in the table at becomes clear that, in addition to covering different syllabuses simultaneously in one class, the teacher should endeavour to emphasise each branch somewhat differently for each candidate, according to the particular examination he is taking. The weight given to ecology and applied biology will very likely interest all teachers of biology.

In column 10 are the percentages of the available teaching *time* the author has spent on each branch in the first year (Science VI Lower 1) of the Sixth Form work. This distribution of time was arrived at by experience, and the figures were compiled from routine teaching diaries kept before the frequency of the occurrence of questions shown in the rest of Table VI was known. It is interesting to observe that the figures in column 10 fall in most cases about the centre of the ranges shown in column 9.

In the City of London School there are 160 hours available in each school year for Sixth Form Biology. The published regulations show that in London University [9] 180 hours are required in one academic year for the General Biology Course for the First Medical Examination for internal students. The time factor, however, does not appear to be important in the search for the causes of strictures upon Sixth Form work, because boys in school may often have two years to cover the work done in one year in the University. One probable cause of criticisms is the need, shown to exist by the evidence in Table VI, to teach different syllabuses simultaneously, coupled with differing emphasis placed upon each branch of biology by different examining bodies.

Moreover, the teacher spends only part of his time with the Sixth Form. He requires his greatest professional skill and relatively more energy for his junior forms, and his school activities outside the classroom may be numerous.

Discussion of Part II.

The foregoing review has attempted to draw attention to aspects of Sixth Form biology seldom considered, but which could be fundamentally important. A discussion of the weighty subject of teaching methods lies outside the scope of the present paper, and deserves to be a matter of separate research. The contents of syllabuses, the nature and influence of University Entrance Scholarship Examinations and the First Medical Examination have all received attention elsewhere in the past.

In conclusion one may venture to depart from a rational and objective approach to the problems of Sixth Form biology and quite frankly indulge in speculation.

A glance at the Higher Certificate syllabuses of Classical and English Studies shows these names: Virgil, Horace, Cicero; Homer, Aeschylus, Demosthenes; Keats, Milton, Shakespeare. Boys in a Classical or English Sixth Form have direct contact with such a company of great minds. It is pertinent to ask whether biological science possesses qualities that can make its study comparable in educational value with that to be obtained by first-hand acquaintance with similar examples of the world's great writers, or whether it is of poor educational value.

One can admit that there is a place in the general scheme of education for a view of the panorama of living nature, or for a grasp of the principles of biological science and for an appreciation of how it is woven into the fabric of human society. These, however, are the utilitarian aspects of biology. By contrast it can be proposed that in a Sixth Form the mental development of the pupils is such that they can recognise that there is a cultural value, to be found in the fact that biological research is a craft, even an art, using the same types of intellectual discipline as the older-established branches of science have developed during and since the seventeenth century.

Furthermore, unlike the student of literature who may depend upon whatever writings have survived until to-day, the student of biology can see the practice of the craft and art of biological research in constant progress. And, what is more significant, he is living in a century probably marked by an intellectual upsurge, in so far as material changes are concerned, no less laden with possibilities and portents for the soul of man than were the times of Pericles or Shakespeare. It can justly be claimed that three is a grandeur, equal to any in the record of human endeavour, to be found among the achievements of biological investigation. To give only one example: the use of selective weed-killers is a direct development, after decades of patient experimentation, from Darwin's curiosity about the direction of growth of seedling shoot tips when covered by small metal caps to exclude light.

It is these cultural aspects, the dramatic and the intellectual discipline, that do not as a rule permeate Sixth Form Science. Is their absence the reason why it is in danger of becoming a stultifying pursuit?

From such thoughts arise questions with far-reaching implications. Will any alteration of syllabuses or of the structure of examinations ever create the true spirit of science in the Sixth Form? Naturally schools vary much in facilities and in the interests of their staffs, and some have, and

take, the chance to break fresh ground. Particularly by field work can a spirit of investigation be fostered. Yet even if one grants that a school should not usurp some functions of a university, it is still possible to contend that science at the Sixth Form level is inevitably stunted if the teachers do not themselves engage in research. Or one may ask if the present methods of training teachers are adequate. Is a university degree, followed by a diploma in education a proper preparation for a career as a teacher of science ?

Naturally here are many problems. But the crux of the matter may perhaps be put thus : research is needed to devise a sound system of teaching that will weld together the various and numerous factors. Not all pupils will go to a university ; any system must harmonise with the frame given by examination regulations ; healthy curiosity and a grasp of the principles of critical methods are essential. Is biology a suitable vehicle with which to reach such an end ? I think it is, provided that we are convinced that it has its own high standards of accurate scholarship, its opportunities for imaginative and constructive thought, and that it is fit to use to enrich and not to impoverish developing minds.

Summary

1. Reports on education published during and since the war of 1939 to 1945 adversely criticise Sixth Form science in schools. This paper records preliminary research into the causes of the dissatisfaction, concentrating on biology.

2. Statistical analyses of the records of the past eleven years at the City of London School, an independent secondary grammar school of 850 boys, indicate that the type of curriculum followed by boys does not affect their performance in biological subjects in the Higher School Certificate Examination.

3. The records of winners of University Entrance Scholarships in biological subjects taken in the Sixth Form show that the type of pre-School Certificate curriculum followed is not a primary factor in success in those Scholarship Examinations.

4. Classification of questions set on biological subjects reveals that the frequency of occurrence of questions upon different branches of biology varies with different examining bodies. This fact, together with the need to teach different syllabuses simultaneously is probably one cause of the unsatisfactory state of affairs.

5. A review of the less frequently stressed, but possibly fundamentally important, aspects of teaching biology to Sixth Forms suggests that in the absence of accurate information to be obtained by further objective research no rational remedies for present ill effects are possible.

6. The point of view is advanced that the basic cause of discontent may be the absence of the true spirit of science from Sixth Form work at present, and that without suitable methods of fostering it no lasting amelioration will be possible.

References

1. 1928. British Association for the Advancement of Science : *Report on Animal Biology in the School Curriculum.*
2. 1932. Economic Advisory Council : *Report on Education and Supply of Biologists.* (H.M. Stationery Office).
3. 1918 and onwards. Oxford and Cambridge Schools Examination Board : *Lists of Successful Candidates.* (Cambridge University Press).
4. 1943. *Curriculum and Examinations in Secondary Schools.* (H.M. Stationery Office).
5. 1944. Royal College of Physicians of London : *Report on Medical Education.*
6. 1944. *Report of the Inter-Departmental Committee on Medical Schools.* (H.M. Stationery Office).
7. 1948. Houslop, N. L., and Weeks, E. J. *The Interests of School Children.* (*School Science Review.* Vol. xxix, No. 109, p. 281 and Vol. xxx, No. 110, p. 7).

8 (*a*). 1943 to 1947. University of London : *Examination Papers for External Students in the Intermediate Examination for the B.Sc. Degree, and in the First Examination for the M.B. Degree.*

8 (*b*). 1942 to 1947. Oxford and Cambridge Schools Examination Board : *Examination Papers Set in the Higher Certificate Examination.* (Cambridge University Press).

9. 1947. University of London : *Faculty of Medicine : Regulations for Internal Students.*

Modern School Biology

By Mr. H. J. Bonham

It was a source of satisfaction to me to know that the British Association was concerning itself with th Modeern School, for it will be a wise and profitable thing to encourage good science teaching in the Secondary Schools which cater for 75 per cent. of the children attending State schools, or, in other words, for those who, at the age of 11 have failed to qualify for entry to the Grammar or Technical Schools.

It seems to me that there are two chief ways in which science is advanced. One way is by the spear points of attack, or the forward patrols into no man's land ; that is, by research. The other way is by the moving onward of the main body of scientific knowledge which should form part of the equipment of the citizen in all walks of life. That way is by the dissemination of scientific knowledge. It is in the latter field that it is essential to include the Modern School, catering as it does for the rank and file of our people.

Now, it is not easy to speak in general terms of the biology, or indeed of any aspect, of the Modern School. In Modern Schools

there is such a great variety that there seems to be no common denominator. A teacher with experience in one or more Grammar Schools could safely proceed from the particular to the general. In such schools there is little variation of organisation. There is the 4 or 5 year course leading to School Certificate followed by the 2 year course for Higher School Certificate and Scholarship. Slight differences in the biology syllabuses of the examining bodies are usually the reason for such divergence as exists. Thus a Grammar School in a rural area and one situated in an industrial area would be following practically the same course for the same examination.

There is no such common syllabus integrating the work done in Modern Schools. Thus, there would be found wide differences in the content of the science course, governed by the situation of the school, whether in a rural or industrial area, the interests and qualifications of the teacher, laboratory facilities and equipment, and so on.

The comparison between Modern School and Grammar School biology can most conveniently be dealt with under three main headings namely, the *aim*, the *content*, and the *method*.

(i) *The Aim.* I believe that in the teaching of biology the ultimate aim in both types of schools is identical, i.e. the development of an attitude which comes from an understanding of biological principles, and a knowledge of biological facts. Such facts should form part of the general knowledge of every intelligent citizen. Thus syllabuses, although they may and do vary in detail, have yet a common core of topics and applications. But it is in the immediate aim that we see a difference, and this difference results in a differentiation of treatment by the teacher.

The immediate aim in a Grammar School is the passing of an external examination. The statement will probably create an outcry, but I go still further to say that it is a justifiable aim. In the past the Grammar School population consisted of two kinds of pupil, those who by their aptitudes and attainments passed the 'scholarship' examination, and those whose parents paid for them to enter, irrespective of whether the children's abilities were such that they could profit by a Grammar School type of education. Under the new Education Act fee paying pupils are not allowed; only those children above a certain level of intelligence and with academic capability can qualify for entry to Grammar Schools. So that from now on it can be expected that most pupils in the Grammar Schools will have some profession in view. Entry to the professions demands that various hurdles should be cleared, the first of which is usually School Certificate or Matriculation. Children are sent to the Grammar School with this object in view and I believe it is the duty of the School to deliver the goods.

There is no such immediate aim in the Modern School, for such examinations as exist are internal ones designed to test the progress of the children in the work covered. But the ultimate aim still stands.

(ii) The *Content.* The content of the pre-School Certificate course in the Grammar School is governed by the syllabus of the examinations taken. This syllabus, on the whole, has been carefully framed to fit the abilities of pupils of the age range 11–16 years, who are being taught in fairly large classes. Detailed dissection and microscopic work are not included in this stage except as demonstrations.

Contrary to what is believed in some quarters, the Modern School, too, has a syllabus. This is worth mentioning because the idea is quite prevalent that Modern School science consists largely of odd snippets of interesting, but unrelated items of information. It is true that in some cases the topic system is used, but the topics are carefully chosen to give some reasoned sequence.

The syllabus in the Modern School, however, is not one imposed from without, but one compiled from within, and subject to modification and variation as is thought to be desirable. Syllabuses as one would expect, vary considerably, according to the individual tastes and capacity of the teacher, the aptitudes of the pupils who may be in an A, B or C stream, and the local conditions. Broadly speaking, it might be correct to say that in many such schools, biology would not appear on the timetable as such, but would be taught as part of a course in general science. Even in a neighbouring Modern School to mine, where the science master is a graduate in botany and zoology and might be considered to be an enthusiast for biology, the course is still one of general science. Naturally, where the headmaster himself is a keen biologist one would expect him to see that biology is given a prominent place in the curriculum. I should say that in most Modern Schools there is rarely more than one science specialist. My own science master is fairly typical—primarily a physicist, he did work on radar during the war and is now slowly working up some biology.

But a considerable amount of instruction in things biological can be given in various ways and by different members of the staff. It is my aim to get as many of the staff as possible interested, and this has been

achieved in the following manner. We have large school gardens and a well equipped orchard. Gardening is taken by at least three of the staff. When outdoor work is impossible lessons can be given indoors on the basis of current gardening operations and the theory correlated with practical work. Thus propagation can be covered, and types of roots, stems and fruits. What more natural than to deal with plant diseases when damping off is found in seedlings, rust on mint or brown rot on a plum tree? Insect friends and foes can be dealt with in the same way. Manurial trials often form part of the gardening course and lessons on plant foods can be correlated with these. Common orchard trees provide a chance to study pollination in detail and subsequent fruit formation, while at pruning time the theoretical basis can be explained with the aid of diagrams, and demonstrated in the garden later. Some Modern Schools keep poultry, pigs and bees. The value of keeping small livestock is not by any means limited to the biological aspect although its use in this direction is obvious.

When a suitable broadcast programme of rural science is available this also is included in the science work, at the appropriate level. I am a great believer in the wise use of radio in the lives of Modern School children, and with their needs in mind I study ahead the programme for the week. Thus I can point out such features as 'The White Scourge' to which older pupils can listen in the evening, since they are never inundated with homework.

Modern methods of teaching domestic science ensure that in the case of the girls, at least, nutrition, food values and vitamins are adequately dealt with. Health education is linked with lessons on physical education, and a period of health education in the classroom succeeds the physical education period in the gymnasium, both being taken by the physical education specialists. In this way the structure and functions of the human body are explained. Where definite sex instruction is found in Modern Schools, it is a fairly common practice for the M.O.H. or school nurse to attend during the pupils' last term at school. Opinions differ as to the advisability of bringing in an outsider, however well qualified, lest it should give undue prominence to this aspect of biology. My own solution would be that sex education should be the normal culmination of a well-planned biology course and should preferably be given by a permanent member of the staff. A course in nature study is included at least in Junior Forms, replaced by social biology at 13 to 14 and then natural history in the last school year. In the social biology course, my aim is to give pupils some idea of the contribution biology has made to the life and well-being of people all over the world, resulting in the increased expectation of life. Such broadcast lessons as 'Lives of the Great Scientists' and those on 'Science and the Community' are of value here. In the natural history course an effort is made to get the children to think along scientific lines and to give them the broad principles of classification. All children need guidance in their observations and it is amazing what archaic ideas have to be dispelled. A typical one is that the presence of a goat in a field can prevent abortion in cows.

To sum up. In my opinion, Modern School biology, as exemplified above, is biology applied to the child and his environment, whereas Grammar School biology may be described as pure or academic. It will readily be realised that when work in biology is shared by so many members of the staff, it is important that provision should be made for adequate correlation. The dangers of overlapping are often magnified, as no two people approach the same topic from the same angle; and there can even be advantages in this, considering that the pupils dealt with are not highly intelligent. Duplication, of course, should be kept within reasonable proportions and correlation is best achieved by the whole of the staff concerned with any contribution to the biology teaching conferring under the chairmanship of the science specialist. On him would fall the task of linking up the various aspects of the subject as he strives to inculcate in the minds of his pupils those broad principles from which might arise the biological attitude, which is the ultimate aim of all the teaching.

(iii) *The method.* The difference in method of treatment of subject-matter in a Modern School as distinct from that in a Grammar School is dictated by two factors:

(*a*) The lower Intelligence Quotient of the pupils. This is sometimes as low as 70 and never higher than 120;

(*b*) the absence of the immediate urge to pass an external examination, for Modern Schools can be completely free from the so-called shackles of outside examinations.

Dealing with the first point. The lower Intelligence Quotient makes it imperative to treat the subject-matter in a simple manner (e.g. to avoid the unnecessary use of difficult technical terms) and to relate it frequently to the pupils' own environment. Thus, methods of presentation must be very different from those for children of a higher Intelligence Quotient. Modern School pupils cannot concentrate for long on abstract ideas. The teacher must strike some

personal chord in the child and then proceed from there. To give a simple example—instead of starting directly on the abstract idea of photosynthesis, one might ask the leading question, 'What did you have for breakfast this morning?' The answer would be readily forthcoming and one could proceed by saying, 'And what did that tree growing outside the window have for breakfast?' Few children regard a tree as living and needing food just as they do themselves, but when their interest has been aroused in this way they are prepared to follow a simple explanation of plant nutrition. Just as students are stimulated to attention by the accounts of recent researches, so the Modern School pupil's interest can be awakened by presenting him with figures from a local newspaper. Headlines such as 'Lower Infantile Mortality—Striking decrease in Lutterworth' at the beginning of a report by the local M.O.H. can be the starting-point of a lesson in social biology which will be followed with much increased interest because the pupils feel the facts are related to their own environment. A local outbreak of foot and mouth disease or the report of a police court case where an analysis of milk found it to be two-thirds water, can produce the same effect for the same reason.

Now for the second point. In Grammar Schools the incentive of the examination—even if it is remote, is felt throughout the school. Parents and teachers often use School Certificate as an effective stimulus especially to weaker pupils. Now what can take the place of this incentive in Modern Schools? The skill and enthusiasm of the teacher are probably the main factors. Children will work well, even at an unattractive subject, if it is well handled by a good teacher, and children do not normally find biology unattractive. We all know how the same lesson given by two different people can produce a totally different response.

Some treatment of the project method may be expected here, but I have had little experience of it and am unable to speak with any authority. I have met and read of teachers who claim great success with this method but there are others who have little use for it and I feel that, at times, it is strained almost to breaking point. Doubtless the method has some very good points, but not every teacher is able to make the best use of it. There is probably much to be said for the short project if the need arises naturally in the normal course, but the large scale project involves the co-operation of practically the whole of the staff and needs careful organisation.

In Modern Schools a larger proportion of time is given to practical work of various kinds. The object of this practical work is twofold—education through the medium of the hand and eye and the acquisition of practical skill. In the case of biology, individual or group dissection is not usually possible owing to few specialist teachers and scarcity of equipment. Pupils are, however, immensely interested in demonstration dissection and in observing living animals or even studying models of them. Very attractive aquaria and vivaria, cared for by the children themselves, are a great source of interest in many schools. Modern School pupils could never be expected to master the intricacies of the microscope and the preparation of slides, but they can examine prepared slides where a microscope is available or, better still, considering the large-sized classes, by the use of a micro-projector. Experimental work is qualitative largely, as opposed to the quantitative methods in the Grammar Schools. It is best done on a large scale and with simple apparatus.

In all teaching these days, increasing use is being made of visual aids, and biology lends itself readily to this method. There is time in the Modern School for the film show—we have recently seen excellent films, showing the life history of a Dandelion and the provision of food by animals for the winter. We have in my school our own film strip projector and I foresee great possibilities as more strips on biological topics become available.

Some progressive County authorities have a comprehensive museum service supplying schools at regular intervals with annotated models and specimens. There is time in the Modern School for organised visits to the central museum itself, where there is usually a nature corner from which pupils can get ideas for their own nature corner in school. Agricultural shows are another source of interest and instruction to which organised visits can be made. Much can be learnt from the exhibits on animal and plant pests and their control, animal foodstuffs and their origin and so on, apart from the livestock itself. These organised visits can be participated in by Grammar School pupils too, but the essential difference is that freedom from external examinations and only partial specialisation allow greater flexibility in the timetable and simplify the organisation of such visits.

Thus in one way and another, a good deal of biology is being taught in Modern Schools. There are signs of increasing interest among the teachers and there is certainly no lack of enthusiasm among the children.

SOME POST-WAR ECONOMIC DEVELOPMENTS IN EGYPT

BY

A. McK. FROOD

EGYPT faces the dual problem of restoring her economy to a peace-time basis and of supporting a rapidly-rising population. The census of 1947 showed a population increase of almost 20 per cent. during the preceding decade and a total exceeding 19 millions. The increase, which was greatest in urban areas, partly reflected war-time changes in economy.

The wealth of Egypt is derived primarily from the cultivation of the alluvial land of the Nile valley and delta, but, because much of the cultivated land produces more than one crop a year, the crop area is greater than the actual area of cultivated land. During the present century the population increase has been at a greater rate than that of the crop area, and thus there has been a steady decrease of both cultivated land and of crop area per head of the population. In 1940 there were only 0·5 feddans of crops, and 0·3 feddans of cultivated land per head. The area of cultivable land in Egypt has been estimated at a maximum of 7·5 million feddans (1 feddan 1·038 acres), which would thus permit the present meagre per capita allowance to be provided for 25 million people. It is against this background of an increasing pressure of population that recent economic changes should be examined.

(*a*) AGRICULTURE

The mainstay of Egyptian economy is the production of cotton, a remunerative crop which has been known to make a net profit of about twice that obtainable from equal areas devoted to rice, wheat or barley. But, although cotton is the most important crop, it has not always been the most widespread, and in pre-war years it occupied about one-fifth of the crop area. In 1937–38, 21 per cent. of the crop area was devoted to cotton, a figure which compares with 18 per cent. for maize, 17 per cent. for wheat and 21 per cent. for berseem (Egyptian clover). The chief varieties of Egyptian cotton include long staples such as Giza 7, Sakel and Karnak, and medium staples such as Ashmouni and Zagora. Ashmouni has long been important in Upper Egypt, but other varieties have been introduced elsewhere as a result of work on the experimental farms of the Ministry of Agriculture.

Egyptian agriculture depends almost entirely on irrigation, but the traditional 'basin' system survives only in parts of Upper Egypt, and is elsewhere replaced by the 'perennial' system by which irrigation canals provide water to the land at all seasons. The perennial system, which permits the cultivation of two or even three crops each year, is made possible by the control of the flow of the Nile, a control which is being extended far beyond the frontiers of Egypt. Egyptian irrigation is concerned with the problems both of supply and of disposal of water. The lack of an adequate system of drainage has resulted both in the raising of the water table, with consequent harm to the long cotton roots, and in the accumulation of salts in the soil to an intolerable degree. Drainage schemes involving electric pumps have been started in the northern part of the delta, but much progress has yet to be made in digging field drains.

By providing almost constant cultivation, and by depriving the land of its annual deposit of alluvium, perennial irrigation tends to exhaust the soil, and, therefore, since about 1900, Egyptian agriculture has been increasingly dependent on the use of imported fertilisers. Between 1937 and 1939 the import of fertilisers (mainly nitrates and superphosphates) averaged more than 500,000 metric tons annually, of which nearly one half came from Germany, Norway and the Netherlands, and nearly one third from Chile. The average consumption of fertilisers per acre was 60 kilograms in Egypt as compared with 38 in Holland, 15 in Denmark and 3 in France.

War-time Changes in Agriculture.

The entry of Italy into the war in 1940, and the consequent virtual closing of the Mediterranean to merchant shipping, gravely threatened the disposal of the Egyptian cotton crop until special arrangements were made. By agreement between the British and Egyptian governments, a British Commission was set up to buy all Egyptian cotton and cotton seed offered, but it was succeeded in 1941 by an Anglo-Egyptian Commission, and in 1943 by a purely Egyptian Commission.

The importance of fertilisers in Egyptian agriculture has been noted, but their supply was necessarily much reduced during the war. European supplies were cut off, and not enough shipping was available to allow Egypt to make up her shortages from distant Chile. But, although reduction in the imports of fertilisers was essential, it threatened to produce a decline in crop yields with consequent serious food shortage. Such a shortage could only be averted either by large-scale imports of cereals, which shipping difficulties made impossible, or by an increase in Egypt's own food production. It was, therefore, decided to divert cultivation from cotton to cereals.

The necessity for such diversion was not realised immediately, partly through the good wheat crop of 1940, and partly through there still being adequate reserve stocks of nitrate until 1941. Moreover, there was reluctance to reduce cotton acreage because of its place in the traditional rotation of crops, but the necessity of importing 150,000 tons of wheat in 1941 emphasised the growing threat to Egypt's food supplies, and in the following year cotton acreage was drastically reduced. Between 1941 and 1942 the percentage of crop area under cotton declined from 19 to 8, whereas that occupied by the principal food grains, viz. wheat, maize, rice and millet, increased in aggregate from 46 to 55. In acreage cotton thus fell to fifth place. The distribution of nitrate was controlled, and its application to cotton was prohibited.

After 1942 a slight expansion in cotton acreage was permitted, and imports of nitrates were increased as far as was possible in consideration of crop surpluses which Egypt made available to the United Nations. Nevertheless, wheat had again to be imported in 1945.

During the war a price fixation policy was adopted by the Egyptian government in respect of cotton, cereals, rice and sugar cane, by which the cultivator was guaranteed a minimum price which allowed for a reasonable profit. This policy reduced the cultivator's dependence on cotton as a cash crop.

Post-war Agriculture.

Egyptian agriculture is still affected by the regulations introduced by the State in 1941. Cotton acreage, although increasing, continues to be restricted to below pre-war levels, and in 1946 the value of the cotton crop represented only 19 per cent. of the value of the twelve chief crops, whereas from 1935–38 the corresponding figure was 37 per cent. There has also been considerable variation in the acreage devoted to different varieties. War-time restrictions had been applied chiefly to medium staples, and towards the end of the war there was an accumulation of long staple cotton in the country. This was later relieved by an increased demand for long staples from U.S.A., India and Europe, and by limitation of acreage of long staples, e.g. in 1947–48 the land devoted to Karnak was reduced to 315,000 feddans compared with 818,000 feddans in the previous season.

During the 1947–48 season there was a sharp increase in the prices of Egyptian cotton, the reasons for which included heavy purchases from abroad (chiefly by the United Kingdom, France and India), a barter agreement with the U.S.S.R., and the fact that Egypt's exportable surplus of raw cotton was only two thirds of the pre-war quantity. Buying was also stimulated by Egypt's willingness to accept payment in sterling. The steeply rising prices of Egyptian raw cotton were increasing the difficulties of British manufacturers and exporters, but in May 1948 the price of Egyptian Zagora fell by 25 per cent., and of Egyptian Ashmouni by 14 per cent. These two medium staple varieties are widely used by Lancashire spinners. This was the first substantial reduction of Egyptian cotton prices since 1941.

The economic stability of Egypt still rests primarily on agriculture, but too great dependence on one crop is dangerous, especially when there is the prospect of increased competition both from other producers and from alternative synthetic fibres. The recent fluctuations of acreage and price of cotton emphasise the need for an agricultural policy. The failure of earlier attempts after 1930 to raise cotton prices by restrictions of acreage suggest that present restrictive practices, although arising from different causes, should not be continued permanently. Moreover, the restoration of cotton to the normal rotation of crops would help to combat exhaustion of the soil which has been produced by recent continuous cultivation of cereals on the same land.

Egypt should also encourage diversification of agriculture. In the past attempts were sometimes made to compensate for the falling price of cotton by raising the price of wheat and maize by means of high tariffs on imports and by subsidisation of wheat exports. The changed crop rotations introduced during the war, combined with the shortage of imported fertilisers, caused a serious decline in the yield and production of wheat and of maize. The yield of wheat, which in 1939 was 6·15 ardebs per feddan, fell in 1947 to 4·27 ardebs, and, although acreage under these crops had increased,

the total production in each case fell below the average for 1935–39.

An attempt to remedy the acute food position so caused was made in March 1948 by a barter agreement between Egypt and the U.S.S.R. which provided for the exchange of 38,000 tons of Egyptian cotton against 216,000 tons of wheat and 19,000 tons of maize. Barter agreements are not without their risks, since they may sometimes result in disguised losses, but the possibility has thus been indicated of Egypt improving her food supplies by means of a revised policy with regard to imports of wheat and maize. Instead of having a policy of protecting wheat and maize, more land now under these crops could be devoted to other more valuable crops intended for export. This is at present the case with rice. It is grown chiefly in the northern part of the delta, and in 1947 its cultivated area had increased by 40 per cent. compared with pre-war. There was a substantial surplus for export which acted as a medium of exchange for some imports of wheat and maize.

Diversification of Egyptian agriculture, with a corresponding reduced dependence on one main crop, might also be considered with regard to other textiles such as flax and jute. Flax production was stimulated during the war, but the quality of the fibre having at first proved disappointing, the acreage was later reduced. Other possible lines of development include an increase of fruit and vegetable production and an improvement and extension of dairying.

All such schemes require a continuation and widening of present agricultural research which has long concentrated on cotton. This would include the development of better varieties of seed and improvements in animal husbandry such as have already begun. Careful attention would also have to be paid to marketing methods including grading and packing, and the provision of credit facilities would also be necessary.

(*b*) Industry

During the early nineteenth century Muhammad Ali Pasha made unsuccessful attempts to convert Egypt into an industrial country, and the failure of these attempts was followed by a long period of prejudice against industrial development. The shortage of imports during the war of 1914–18 encouraged the establishment of a number of small industries which later had difficulty in meeting competition from imported goods. After 1930, with the termination of the last of her treaties under the capitulatory regime with various foreign powers, Egypt was able to impose tariff protection for her local manufactures, and the level of this protection has steadily risen. The growth of Egyptian industries since 1930 is indicated by the 1937 census which showed that 60 per cent. of the total had been founded in the preceding decade.

Egyptian industries are based mainly on the processing of local products both in large factories and in numerous small establishments. It is estimated that more than 750,000 people are employed in Egyptian industry, but this number represents less than 5 per cent. of the total population. Moreover, the bulk of industry is concentrated in Cairo and Alexandria, although the chief centre of textile manufacturing is now at Mehalla el Kubra in the delta.

Before the war the greatest industrial progress had been made in the textile industry. Between 1930 and 1939 the output of cotton piece goods increased sixfold, and, at the outbreak of war 40 per cent. of the local demand for cotton cloth was met out of local production. Nevertheless, textile materials and manufactures accounted for one-fifth of the total Egyptian imports in 1938, and they constituted the largest single item of imports. The import of raw cotton into Egypt was prohibited and thus high grade expensive Egyptian cotton had to be used in the local manufacture of low-quality goods. Silk weaving was also of importance, and some woollen and linen goods were produced.

The processing of agricultural products naturally played a large part in the structure of pre-war Egyptian industry. The whole of the cotton crop was handled by the long established ginning and pressing factories of which two-thirds were in Lower Egypt. Cotton seed presses dealt with only about one third of the total seed, and of the cotton seed oil so produced about two-fifths were consumed locally as oil, one-fifth was exported and the remainder was used in the soap industry. Large quantities of ordinary household soap were manufactured and also a small quantity of toilet soap. At the outbreak of war the soap industry could meet about 90 per cent. of local requirements. Egyptian soap was chiefly made from cotton seed oil and caustic soda, both being indigenous products, but some olive oil for soap making was imported from Greece, Syria and Palestine.

Other industries based on the processing of local agricultural produce were the milling of wheat and rice which were estimated to employ some 50,000 people. Imports of wheat were virtually stopped by the protective duty imposed in 1930 and this stimulated the milling industry, but, although

some modern mills were introduced, the great majority were still of a primitive stone pattern. Rice milling also increased with the expansion of the rice crop. The crop was grown chiefly in the northern part of the delta where also were the principal milling centres viz., Alexandria, Rosetta, Damietta, Mansura and Mehalla el Kubra. The mills of Alexandria were equipped with machinery capable of milling rice to a standard acceptable in European markets. The rice milled elsewhere was either exported to Asiatic markets, especially Palestine and Turkey, or was consumed locally.

The cultivation of sugar cane in Egypt began about 1850, but from 1855 until 1881 the sugar industry was confined to the extraction of raw sugar which was then sent to Marseilles for refining. A number of sugar mills and refineries were later established, and in 1902 were concentrated into a monopoly whose prices and profits have been controlled by the government. The refineries deal with imported as well as Egyptian raw sugar, and in 1939 Egypt was completely self supporting in sugar and had a surplus for export. Of the output of molasses about a quarter was exported and the remainder was used in producing alcohol.

An example of an Egyptian industry which depended completely on imported supplies of raw materials was the manufacture of cigarettes. Tobacco came mainly from the Balkans, but, in face of high customs duties, cheaper tobacco was also imported from China and Japan.

The fishing industry normally employed some 50,000 men and 20,000 boys, and the annual catch was worth about £E1,000,000. Nevertheless, fish provided only a small contribution to Egyptian diet; the per capita consumption being less than one ninth of that in Britain or in Japan.

Egypt lacks coal, but petroleum is obtained from both sides of the Gulf of Suez, chiefly at Hurghada (Ghardaqa), Ras Gharib and Abu Durba, and pre-war annual production was about a quarter of a million tons. At Suez there was a governtenm controlled refinery which refined much imported as well as Egyptian crude oil.

In pre-war years Egypt's proven mineral resources did not provide the basis for an iron and steel industry, but in 1937 there was announced the discovery of extensive, high grade iron ore deposits in the desert about thirty miles east of Aswan. The ore deposits promised relative ease of extraction and smelting, but they had not been exploited before the outbreak of war. Other mineral resources which were being exploited included phosphates from the Red Sea coast near Qoseir and Safaga, manganese from western Sinai and salt, all of which provided a surplus for export.

War-time Changes in Industry.

The abnormal conditions of war-time provided a very great stimulus to Egyptian industries. The demand of the Allied forces combined with the scarcity of imported goods caused sharp rises in prices and in profits. Moreover, with the establishment of the Middle East Supply Centre in 1941, emphasis was laid on the increased development of local sources of supply in order to save shipping space. Thus there followed an expansion of existing industries and the creation of new ones.

Greatest progress was made in the textile industry. The output of cotton yarn increased by 44 per cent. between 1938 and 1942, and that of cotton cloth by 58 per cent. between 1938 and 1944. Wool and silk production also increased considerably, and, although an experiment in increased flax production yielded fibre of disappointing quality, it was accompanied by an increase in the number of local scutching and retting mills. In addition, a jute mill was set up near Cairo and used imported jute. In 1944 two fifths of the whole industrial population of Egypt were employed in textile manufacture.

The manufacture of foodstuffs expanded considerably, and in 1944 industries of this category employed one fifth of the Egyptian industrial population. Dehydration of vegetables was introduced, sugar refining and the manufacture of dairy products increased, and there was a spectacular expansion of output of preserved and canned foods.

The chemical industry also increased both in volume and in range of products, and light branches of mechanical and electrical engineering expanded to meet the demands of maintenance and the need for supplies of spare parts.

Egypt's production of petroleum increased fivefold during the war and Egyptian oil refineries were able to supply more than all the civilian requirements for petrol and for asphalt. Furthermore, they were able to supply about 60 per cent. of the civilian fuel oil requirements despite the great increase in such requirements caused by large scale conversion from coal to oil firing both on the Egyptian State Railways and in the cement industry.

The distribution of industry in Egypt shows a marked concentration on Cairo, Alexandria and the central provinces of the delta. According to the Census of Industrial Production for 1944, almost two-fifths (39·4 per cent.) of Egypt's industrial works were found in Cairo and Alexandria,

and a further 32·1 per cent. in the deltaic provinces of Gharbiya, Minufiya and Qaliubiya. Upper Egypt is as yet much less affected by industrialisation. In 1944 it accounted for only 16·4 per cent. of the total industrial workers, and of these one half were in Qena and Giza provinces. It may be noted that the factory workers of Giza and Qaliubiya provinces are mainly within the industrial orbit of Cairo, and that thus what might be regarded as greater Cairo employs no less than one-third of the total industrial workers of Egypt.

Post-war Industry.

The relative scarcity of industry in Upper Egypt may in future be changed by developments in the neighbourhood of Aswan. In March 1948, there was laid the foundation stone of a hydro-electric power station at Aswan dam. This is intended to form the beginning of a plan for linking all parts of Egypt in a vast electricity network. Such a plan might have an important bearing on agriculture, since, if cheap power became available, the irrigation of additional land on the desert edge by pumped water might become profitable. The scheme also envisages the large scale production of synthetic nitrate, which would greatly reduce Egypt's dependence on imported fertilisers, and a further aim is the establishment of a basic iron and steel industry which would derive its ore supplies from the rich deposits to the east of Aswan.

Industrial activity has been maintained since the war, but with difficulty. Much equipment is obsolescent and its renewal is a major problem. The expansion of industry will largely be related to the size of the internal market, which as yet remains limited by the poverty of the population and by high production costs. The virtual state of monopoly created by the war stimulated an exaggerated rise in industrial prices and profits and thus an excessive increase in general expenses. Unless such production costs are lowered it is doubtful whether the less well established Egyptian industries will be able to withstand foreign competition or to expand their domestic market.

(*c*) Foreign Trade

Pre-war Conditions.

During pre-war years Egypt normally had a favourable visible balance of trade, which between 1933 and 1937 averaged more than £E2·3 millions. In 1938 this favourable balance was reversed, mainly as a result of the fall in cotton prices which had begun in 1937, but other 'invisible' items had also to be considered in assessing Egypt's economic situation. Her income, which normally benefited from tourism by about £E 1 million annually, was also increased by a proportion of the Suez Canal shipping dues, by the coaling of ships at Port Said and by the expenditure of British forces stationed regularly in the country. Against these items had to be set the cost of foreign banking, shipping and insurance services, although the development of Egyptian companies was beginning to reduce the size of this debit item.

The character of Egypt's pre-war foreign trade showed a marked contrast between exports and imports. Whereas exports were dominated by one item, namely raw cotton, imports were much more diversified. Raw cotton, together with its by-products cotton seed, cotton seed oil and cotton seed cake, regularly accounted for four-fifths of the value of all Egypt's exports. Onions and rice were also important, and other agricultural exports included eggs, flax, sugar, wheat, hides, skins and raw wool. Mineral exports were slight and were chiefly phosphates from the Red Sea coast and manganese from western Sinai and mineral oils. The only manufactured exports of note were cigarettes. Thus Egypt's exports consisted almost entirely of primary products. The range of imports was much wider. Its main categories were textiles (chiefly cotton piece goods), metals and machinery, fuel, fertilisers, vehicles, wood, and tea, coffee, sugar cane and tobacco. Many of these items were not produced in Egypt at all, but some were those in which local production or manufacture were insufficient to meet local needs. Moreover, certain raw materials, e.g., crude oil, sugar cane and tobacco leaf were imported and processed before being re-exported.

The direction of Egypt's pre-war foreign trade was such that her best customer and leading supplier was always the United Kingdom, which in 1938 took 33 per cent. of Egypt's exports and supplied 22·9 per cent. of her imports. The United Kingdom's share of Egyptian trade had gradually fallen during the preceding fifty years, but she remained the chief buyer of Egypt's primary export, namely raw cotton. Furthermore, her share was more than three times that of any other country, and it was comparable with the aggregate for four countries of Western Europe, viz., France, Germany, Italy and Belgium. A relatively small part in Egyptian trade was played by the U.S.A. and India.

War-time Changes in Foreign Trade.

The adverse nature of the visible balance of trade which had developed in 1938, became much more pronounced during the war largely owing to severe restrictions on

exports which were designed to alleviate local shortages, and which in part were also caused by the difficulty of shipping Egyptian raw cotton. Exports of raw cotton were confined only to the essential needs of the United Nations, and much cotton purchased by the United Kingdom remained unshipped. Egypt's exports remained below the 1939 level until 1945. From 1941 onwards imports were controlled by licences issued by the Egyptian Government in agreement with the Middle East Supply Centre. The increased values of imports during the war did not imply a corresponding increase of volume since they were largely produced by rising prices.

It should be noted, however, that the adverse balances of Egypt's visible trade with the United Kingdom were not related to the balance of payments between the two countries. During the war the United Kingdom incurred very heavy expediture in Egypt, including the cost of contracts placed in Egypt, payment for services to the armed forces, and expenditure by the troops in Egypt, so that at the end of the war Egypt was left in command of sterling balances which were estimated in June 1945 at £400 millions.

The war-time limitation of markets and of sources of supply, together with the constant need to save shipping space, altered the direction of Egypt's foreign trade. The important pre-war trade with western Europe virtually ceased, but an increased share was taken by the U.S.A., India and some Middle Eastern countries such as Iran, Iraq, Turkey and Palestine.

Post-war Trade.

Since the war there has been a steady increase in the value of both imports and exports. The adverse balance of visible trade has been reduced by greater exports of cotton, but it remains at about £E15,000,000. The surplus of imports over exports reflects Egypt's desire to replenish her industrial and agricultural equipment, and this re-stocking is being achieved without recourse to credits or loans, but by utilising the balances which she accumulated during the war.

Financial agreements regarding Egypt's use of her sterling balances were made with the United Kingdom in June 1947 and again in January 1948. These agreements were followed by the relaxation of import controls on goods from the sterling area, and in June 1948 from France.

In the distribution of Egypt's foreign trade the European continent is resuming an increasingly important role. In 1947 Europe accounted for about 35 per cent. of Egypt's total imports, compared with 20 per cent. in 1946, and for about 45 per cent. of Egypt's exports as against 35 per cent. in the previous year. Britain remains Egypt's chief supplier (with 22·1 per cent. in 1947), and is followed by the U.S.A., Italy, France and Belgium. Egypt's best customer, however, in 1947 was India (16·8 per cent.), followed by the United Kingdom (14·7 per cent.), Italy and France.

Egypt's visible deficit in her balance of trade in 1947 was mainly with the hard currency countries, thus it seems that she may attempt to remedy this by increasing her imports from the sterling area, and by directing her exports as far as possible to the hard currency countries.

In three different fields—agriculture, industry and foreign trade—Egypt is attempting to adjust her economy to post-war conditions, but, although she is at present a relatively prosperous country, she has still to solve the long term problem of supporting her rising population.

(*Paper read to the Geography Section of the British Association on Sept.* 10, 1948, *during the Annual Meeting at Brighton.*)

THE TRAINING OF THE GEOLOGIST

Report of a Discussion

Much of the substance of the discussion received appropriate introduction in the remarks of Dr. A. E. Trueman on ' Geology in Education ' in his presidential address to Section C (*Adv. Sci.*, No. 19, 1948, p. 185ff.). Referring to the general lack of geology teaching in schools, he emphasised the high cultural value of the subject particularly in providing the layman with a sense of cosmic proportion, a time-scale of terrestrial history, and so enabling him to appreciate with real understanding the late place of human evolution and human history in a succession of events going back some thousands of millions of years. He thus put stratigraphy (as geological history) in a central position in geological teaching. He also insisted on the importance of field work—which, leading to inference from observation, served as the best introduction to scientific method—to the teaching of the subject : in this, he was echoed by several speakers in the discussion.

Since different groups of university students study geology with different ends in view, Professor Neville George argued that the contents of their courses and the techniques of their training should show corresponding differences. On the purest of non-vocational levels university ' subjects ' had value and were to be approved by authority because of their use and importance in the transmission of culture, in the propagandist conditioning of the well-informed citizen. Once the need was recognised for a genuinely cultural pabulum (' cultural ' in being a compendious introduction to social context) students found it met on its scientific side as well by geology as by any other science, and the subject had high claim to a prominent place in ' liberal ' university teaching. Its special attractions had already been amply considered in discussions at meetings of the British Association in 1937 and earlier years, and of the Geologists' Association in 1947. A first kind of geological student was then the non-professional kind wanting an introduction to geology as an illustrative scientific discipline.

A cultural course in geology was only incidentally concerned with ' facts ' and technical methods and explanations. In themselves, the Wealden succession in Sussex or the Dinantian succession in Northumbria, the facies contrasts between paralic and limnic coals, the opposed mechanics of lag and thrust faults, the differences between tholeiites and olivine basalts, should find no intrinsic place in such a course : not because they were matters too detailed, but because they lay outside its framework—though of course as convenient examples they might well be used to illustrate principles. In the same way, the acquisition of high skill in the use of polarised light for the precise identification of minerals, or in the use of specialist monographs for running down fossil species, was a diversion in which end was overlooked in a concentration on means.

The intention of a cultural course was to introduce the student to the nature of geological evidence and to the manner of geological argument, to provide a conspectus of current geological knowledge (including ' knowledge,' such as that of granitisation, which was still the ground for major debate), and to place the student in a physical and chronological background in such a way as to make him quite literally feel at home in the world.

Professor George suggested that a major element in such teaching was a consideration of geological agents and processes, and of landscape evolution, that should combine the presentation of synthetic descriptions of rock-origins with an appreciation of geological environments of rock-formation. In the classical tradition, this would combine Huttonian and Lyellian principles with echoes of part of Huxley's physiography ; and, in discussing present land-forms by reference to structure and process, would be essentially an introduction to geomorphology on the lines popularised by W. M. Davies.

A second major feature in such teaching was the elucidation of the incidence of geological change, which was most effectively achieved (as Dr. Trueman pointed out) less by a statement of the calendarial chronology of events in years than by an emphasis on the palaeogeographical revolutions revealed by stratigraphy, and on the broad stages of landscape evolution. In this approach additive details of stratal succession were not merely superfluous but positively detracted from clear understanding : that the Ordovician period was a time of powerful volcanic activity was of much greater importance than that its beds could be subdivided into a number of graptolite zones. The wider the regional extent of the rock-unit, and the

broader its facies-range, the more readily comprehensible was the succession of changing environments to the neophyte who was always to remain an amateur ; and the more intelligently could he in due course (if the occasion should arise) fit further detail into his conspective background of knowledge.

A third major feature, involved in the second, was the picture of organic evolution that emerged when the significance of fossils and of the stratigraphical time-scale was grasped. Geology continued to offer the main evidence of long-term and large-scale evolution ; and in providing the essential foundation for the studies of neontologists on evolutionary processes presented the most acceptable and balanced scientific (as opposed to sentimental) view of terrestrial human setting. This was not a plea for the introduction of morphological palaeontology into such a course : the sweep of discussion should be in terms of families and orders, if not phyla. Nor was it a suggestion that palaeontology should be more favourably treated than petrology. It merely contended that with a particular end in view broad-scale treatment of evolution was a very proper means.

Such a course, provided for the great majority of university students of geology who would never become professional geologists, should serve as a touchstone to carry back into the schools, where, as Mr. F. P. Insley deplored, exorbitant and largely misguided demands were made upon pupils to absorb a host of factual details that inevitably tended to submerge understanding in learning, and that marked the content of the syllabus as determined by advanced university requirements.

On a basis more immediately *ad hoc*, geology had a functional use in various fields of technological specialisation that made it a ' required ' subsidiary or adjunct subject. To geography it was foundational. In civil engineering, mining, metallurgy, and agriculture its applications were direct ; in chemistry, archaeology, and biology its applications were more devious. A second kind of geological student was the kind wanting selected and appropriate parts of the science helpful to a better understanding of his main subject of study.

The contents of courses in applied geology differed widely from institution to institution for a variety of reasons. Being designed for a restricted purpose, they were seemingly best determined by the applied scientists who made the applications ; and engineers asked for lectures on foundations and on water supply ; miners for lectures on tectonics ; agriculturalists for lectures on soils ; metallurgists for lectures on ore deposits. These special demands carried the assumption that applied geology was something distinct and different from geology not immediately ' applied,' and that the contents could be fed to students as special concentrates. Nevertheless, there was marked disparity between the demands of different institutions ; and the uncertainty of what was expected in applied geology was indicated for instance in civil engineering by the requirement in at least one university of a two-year course in geology for Final Pass as opposed to the requirement in several other universities of only two terms of geology for Honours.

Applied geology was in fact no more than geology applied. Doubtless, special lectures in selected branches were specially useful in indicating the variety of its applications ; and a biologist studying fossil evolution would not want the same information as a geographer wishing to make a land utilisation survey or a metallurgist concerned to know the geological relations of Cumberland haematite. Nevertheless, the basic elements of what was applied remained the same for all specialists ; and a desirable foundation to all applied geology was a balanced course in general principles that initially should contain no reference to lines of special application.

A request for spoon-fed particulars, crammed into as brief a course as possible, indicated a misconception of what ancillary applied geology involved. It could not be designed to enable the applied scientist to solve all, or indeed any, of the technical geological problems he was likely to meet. As Professor Legget insisted, a training in applied geology was a training in the relevance of geology to some other discipline : it should instruct the applied scientist sufficiently to prompt him at the right time to see the significance of geology in his professional work, to make him intelligently aware of the occasion when he was faced with geological problems, and to suggest to him what precisely was the nature of those problems and how best they could be overcome. University courses in applied geology should be left to the professional geologist and not to the applied scientist.

A third kind of geology student was the kind who studied geology because he proposed to become a professional geologist.

Professor George suggested that difficulties in training the professional geologist arose from two main causes. Apart from a few large institutions, most universities were, or had been until recently, understaffed, in the sense not merely that students numbers were proportionately large and individual attention was correspondingly perfunctory but also that each university teacher could give expert and first-hand instruction in only a

relatively small part of the whole field of learning. And in most universities the full Honours course in fact occupied only three years (whatever permissive regulations there might be about four years), which, as Mr. P. Evans stressed, was much too short a period to allow students adequately to cover a reasonably comprehensive syllabus. These difficulties were partly expressed in the divergences between the courses of different universities.

There was general agreement concerning the syllabus for the first two years of study, in which elementary introductions to mineralogy and petrology, physical geology and tectonics, palaeontology and stratigraphy were usual; but in the succeeding year or years specialisation of study and a consequent restriction of the syllabus were customary.

This specialisation sometimes took the form of training students in selected branches of geology with a view to making them technically expert as particular kinds of applied geologists. The result was no doubt to produce graduates who were certainly immediately useful on first appointment, but who were nevertheless essentially skilled practitioners who had acquired a special dexterity in certain technological fields. They were not (except by supererogation) analytical scientists having a significantly profound understanding of geology—nor (in justice to their education) were they intended to be. They were trained to be servants of particular industries.

In most universities, however, there was no formal compartmentalisation of courses in geology. Nevertheless there was frequently (perhaps usually) a tendency to restrict courses, if only in weight of emphasis, in such a way as to make the graduating student a quasi-specialist. The extremes were reached in some institutions where the Honours graduate might be examined in any one of three or four separate branches of geology; and where the amount of overlap in the examination questions of the several branches was nil.

Mr. P. Evans strongly advocated the view that specialisation in training was to be avoided: the specialist who was not first and foremost a geologist, and the geologist who was only a technican (and not also a technician) were scarcely to be regarded as desirable university products. The trained student should be aware of contrasted points of view in many geological matters, and should be inspired by an informed scepticism that enabled him to assess evidence and draw conclusions with some measure of objective judgement: a university training was lacking which did not encourage a critical attitude to current theory.

More general was the attempt at producing the adequately trained geologist by putting on the frail foundations of the introductory course a series of super-structures that were more or less independent and non-developmental, and that neither intensified and broadened the student's geological knowledge (even in one field) nor gave him a salutary awareness of his own defects of ignorance. Fragmentation of 'Honours' work (a few lectures on continental drift, on Alpine structures, on granitisation, on theoretical palaeontology) might allow the discussion of topical and intriguing (but temporary) problems, which in their turn might provide excellent commentary on orthodox knowledge, but unless re-integrated on a broad foundation it did not provide the substance of geology.

Almost universal was the comparable discrete partitioning of courses (frequently necessitated by limitations of staff) into specialisms that were a reflection of the interests of the teachers, and that were in themselves pertinent and indeed essential elements of sound geological education provided there was correlation between the contents of these independent specialist groups of lectures. But without that correlation the cumulative effect was not progressive but one of additive accretion; and while the teachers themselves might realise that the apparent fragmentation was only a superficial inevitability of the lecture-system, and might regard the syllabus as coherently full in intention, the student who was expected to have the same discernment was in fact, through his own ignorance of what the fields of geology were, precluded from making the expected synthesis.

In the content of the geology taught, Mr. Evans thought that interest in fundamental principles should not be submerged beneath a too parochial concern with local detail. A knowledge of lists of stratigraphical zones was of far less importance to the student than acquaintance with the factors on which the zones were established; knowing the principles he then needed only guidance in the search for descriptions of stratigraphy in any particular area. Similarly, the recognition of fossils in terms of names should be entirely dispensed with: with a grounding in morphology the student should only need to acquire competence in the use of monographs for making his identifications. Stratigraphical, lithological, and palaeontological details were important only as illustrations of general principles.

The fostering of a wider outlook in terms both of terrain and of method was greatly to be desired in Britain: for instance, Swiss ideas of structure, photogeology, statistics

in palaeontology received unduly little attention, and too often surveying was completely neglected.

Most geologists would be surveyors of one kind or another ; and as such they would meet a great variety of problems of all kinds —problems unpredictable in their nature and in their ramifications. Dr. H. Dighton Thomas supported the view that university training which was not carefully planned or which was only partial made its products to that degree imperfect, and impaired their competence. When granite was once sediment, when Moines were Torridonian, when coalfield exploitation was dependent on detailed knowledge of community evolution, when structures in Somerset might disclose what lay buried in Kent, it became inadvisable to specialise in training. Even for the intentional specialist, the museum curator or the university lecturer, he who was aware of the geological context of his specialism was thereby the better specialist. As for the exploratory geologist of overseas surveys, working in country where what he was likely to meet was almost completely unknown, the broader and more general and more comprehensive his geological knowledge the more efficient geologist would he be. Certain conclusions seemed to follow : university courses should be integrative and not compartmentalised, reasonably comprehensive and not particulate ; staff should be adequate in number and varied in interest ; a full four-years Honours course, because of the mere quantity of matter to be conveyed in the teaching, was to be taken for granted (as it was taken for granted, directly or indirectly, in Physics and Chemistry, Botany and Zoology).

Professor Duncan Leitch and Professor George emphasised it by no means followed, however, that there should be a dead uniformity of factual didactic information to be conveyed in all courses in all universities in all branches of geology. University training should have for its product the graduate geologist who was sufficiently knowledgeable to be able to tackle any geological problem he was likely to meet : it was then instruction in and discussion of principles rather than the transference of the contents of an encyclopaedia. Unless teaching was to be medievally scholastic, principles could never be taught without constant reference to fact (and with intensifying studies to a multiplicity of facts) ; but there obviously could and should be intelligent selection of significant fact (and rejection of superfluous fact) to illustrate the principles the application of which in due course was the ultimate intention of the training. Intelligent selection was a necessary part of the teacher's work—not least, to point the significant analogy and to encourage a power of synthesis—and the intelligent teacher would inevitably make his own selection.

The danger of regarding geology too much as a classroom subject was referred to by Mr. Evans, Mr. W. H. Wilcockson, and Professor George. Learning could never be *in vacuo*. It was always to be related to experience. The meaning, the significance, of geological phenomena were only to be obtained when verbal lectures were supplemented by appropriate and ample practical work. Of this, the handling of laboratory specimens and the geometrical ingenuities of laboratory map-analysis, though important, formed only a minor part. Geology was a field study, and far too few university students obtained adequate field experience. Brief annual conducted tours and local day excursions, though essential in introducing the student to a variety of formations, structures, and terrain, were wholly insufficient. Perhaps the foremost element in geological training was individual field work —map-making which should involve stratigraphy and structure, a mixed series of rock types, and a geomorphic expression of geology.

Professor H. H. Read referred particularly to training in research. Since many more students were capable of learning what they were taught than were capable of making any original contribution to knowledge it was a disservice to geology (and incidentally to the students) to encourage the average graduate to undertake research. Most technically qualified geologists, competent as judged by certain specification standards, were without the vital ' spark '—that combination of curious mind and discerning eye —that was a prerequisite of true research ability. They might be safely entrusted with routine duties, including routine mapping, for which their qualifications equipped them ; and could no doubt make novel contributions to knowledge when working under the inspiring guidance of research directors. But it should never be supposed that the kind of training given and the kind of success achieved in undergraduate courses had necessarily any relation to future promise in research; and there should be careful and drastic weeding out of the enlightened from the merely skilful.

High-quality research required directors largely free from the burden of other duties. Its atomisation amongst a large number of university departments, each working more or less in isolation, each with comparatively few students limited in their contacts, each served by a relatively small staff the greater part of whose time was taken up in routine

undergraduate teaching, was both wasteful and inefficient. The organisation of university post-graduate work in Britain, Professor Read thought, should be concentrated in perhaps three or four centres, each of which could then afford adequate room, staff, and equipment, and in each of which there would be a research community self-enriching by constant internal discussion and exchange of ideas.

The smaller and more 'provincial' university departments could then be freed from one part of their doubly onerous work, with consequent improvement of the quality of their undergraduate tuition. A selection of more promising students on graduation would pass on to the research centres for further training.

Mr. Evans extended the last view to include Honours courses, and thought that when all universities in such a small country as Britain professed to teach geology to Honours standard, thorough courses which kept abreast of modern developments were scarcely possible. Unless the number of Honours students turned out was going to be excessive, half or more of the Honours schools would have so few students as to be unable to claim an adequate staff or adequate facilities; and with fewer universities teaching geology departments could be better staffed and better equipped.

Mr. Evans added two further points. In the first place, there was need on the part of all professional geologists for a sound grounding in other branches of science than geology. The foundation should include three or four of the subjects Chemistry, Physics, Biology, Mathematics, taken at least to the standard of a First Year university course.

And in the second place, the competent geologist should be able to express his views and his findings in words. Universities took competence in literary expression too readily for granted: training should include the writing of essays of various kinds in which skill in presenting a thesis was supplemented by knowledge of where to find and how to extract information from relevant publications. The use of technical terms to give precision was to be encouraged; but a revelling in a fashionable jargon, which was likely to put the student in danger of thinking that a vague word was a substitute for an explanation, was to be deplored.

In summary, his conclusion was that a satisfactory university course for the professional geologist should embrace good groundwork in non-geological sciences, an avoidance of over-specialisation, and a thorough knowledge of English.

T. N. G.

(*Report of a discussion in the Programme of Section C at the Brighton Meeting in* 1948.)

THE TEACHING OF GEOLOGY IN SCHOOLS

INTERIM REPORT of COMMITTEE appointed to consider and report on questions affecting the teaching of geology in schools—Dr. A. E. Trueman, F.R.S., *Chairman*; Dr. Mabel E. Tomlinson, *Secretary*; Prof. A. H. Cox, Mr. J. Davies, Miss Gaynor Evans, Prof. W. G. Fearnsides, F.R.S., Prof. G. Hickling, F.R.S., Prof. D. E. Innes, Prof. W. J. Pugh, Dr. A. K. Wells, Miss M. A. Arber, Dr. L. R. Moore, and Prof. A. Wood.

Result of Enquiry into Geology as an Examination Subject in Schools in Great Britain

Early in 1948 an enquiry into the position of geology as an examination subject was addressed to each of the Examining Bodies whose names are given below.

University of Bristol Examination Council, University of London Matriculation and School Examination Council, Northern Universities Joint Matriculation Board, Oxford and Cambridge Schools Examination Board, University of Durham School Examinations, University of Cambridge Local Examination Syndicate, Central Welsh Examinations Board, Oxford Local Examinations, Scottish Education Department, Northern Ireland Ministry of Education.

We should like to record appreciation of the promptness and courtesy with which the enquiry was answered by all these Examining Bodies.

School Certificate

Two Examining Bodies set papers in geology at this stage.

Central Welsh Board, Durham University.

Northern Universities set questions on geology in a General Science paper.

Since 1947 Cambridge Local Examination Syndicate has also included geology in General Science.

HIGHER SCHOOL CERTIFICATE (SUBSIDIARY STAGE)

Four Examining Bodies offer Geology at this level.

Northern Universities, University of Durham, University of Cambridge Local Examination Syndicate, Oxford and Cambridge Schools Examination Board.

HIGHER SCHOOL CERTIFICATE (PRINCIPAL SUBJECT)

Five Examining Bodies set papers in geology at this level.

University of London, Northern Universities, Central Welsh Board, University of Durham, University of Cambridge Local Examination Syndicate.

HIGHER SCHOOL CERTIFICATE (SCHOLARSHIP)

The Northern Universities set papers in geology at scholarship level.

Cambridge Local Examination Syndicate set advanced papers in Geology for Principal subject. The advanced papers may be considered to be similar to scholarship papers.

There has been a marked increase in the number of candidates offering geology for examination at all levels.

	1942	1943	1944	1945	1946	1947
School Certificate	128	116	167	248	164	270
Higher School Certificate (Sub.)	7	8	31	42	57	110
Higher School Certificate (Princ.)	17	16	24	39	63	93
Higher School Certificate (Schol.)	0	1	1	5	7	12

The number of schools presenting candidates for examination in geology has shown a steady increase.

	1942	1943	1944	1945	1946	1947
School Certificate	13	15	17	23	20	30
Higher School Certificate (Sub.)	5	9	19	29	25	36
Higher School Certificate (Princ.)	11	12	13	27	32	44
Higher School Certificate (Schol.)	0	1	1	3	6	9

SEISMOLOGICAL INVESTIGATIONS

FIFTY-THIRD REPORT of COMMITTEE on Seismological Investigations (Dr. R. STONELEY, F.R.S., *Chairman*; Lt.-Col. E. TILLOTSON, *Secretary*; Mr. E. F. BAXTER, Miss E. F. BELLAMY, Prof. P. G. H. BOSWELL, O.B.E., F.R.S., Prof. E. C. BULLARD, F.R.S., Dr. G. E. R. DEACON, F.R.S.; Dr. A. T. J. DOLLAR, Dr. A. E. M. GEDDES, O.B.E., Prof. G. R. GOLDSBROUGH, F.R.S., Dr. WILFRED HALL, Dr. O. J. R. HOWARTH, O.B.E., Mr. J. S. HUGHES, Prof. H. JEFFREYS, F.R.S., Mr. COSMO JOHNS, Dr. A. W. LEE, Prof. H. H. PLASKETT, F.R.S., Dr. A. O. RANKINE, O.B.E., F.R.S., Rev. C. REY, S.J., Rev. J. P. ROWLAND, S.J., Dr. F. J. SCRASE, Dr. H. SHAW, Sir FRANK SMITH, G.B.E., K.C.B., Dr. J. M. STAGG, and Mr. P. L. WILLMORE.)

Personal.—The Committee deeply regret the death of Mr. J. J. Shaw, C.B.E., at the age of 74. For some 31 years he was Secretary of this Committee, and he was regarded with affection by all those seismologists who were privileged to know him personally. The Milne-Shaw seismograph, a horizontal pendulum instrument embodying many improvements on the old Milne type, has been of outstanding service to seismology. By permission of the Editors of *Nature*, Lt.-Col. E. Tillotson's obituary notice of Mr. J. J. Shaw is reproduced below.

I would like to add my personal appreciation of Mr. J. J. Shaw's enthusiasm for seismology. My first acquaintance with a seismograph dates back to a visit to Shide in the company of Prof. H. Jeffreys early in the first world war. Milne's old observatory was being run by Mr. J. H. Burgess, and it happened that both Mr. J. J. Shaw and Prof. H. H. Turner were there on a visit. Owing to war necessity, time signals were not radiated, and the time was obtained by a portable transit instrument, using a saucer of treacle as an artificial horizon.

Mr. J. J. Shaw's exposition of the principles and working of his instrument made a lasting impression on me, and it is typical of him that when I next met him, at the I.G.G.U. meeting in Madrid in 1924, he greeted me as an old friend. One of his last letters on seismological matters must have been one received by Prof. the Rev. J. B. Macelwane, S.J., at St. Louis just before Mr. J. J. Shaw's death was reported ; in this he referred cheerfully to his forthcoming operation, and Shaw's remarks concerning his experiments of the simultaneous recordings of microseisms (1921 Report) showed that his mind was still vigorous and his enthusiasm unabated.

The Committee offers its congratulations to Dr. E. C. Bullard on his appointment as Professor of Physics in the University of Toronto, and on being awarded the degree of Sc.D. by the University of Cambridge. While regretting that Great Britain will lose the contact with his energetic personality, it is pleasing to know that he will have enhanced opportunities of prosecuting his geophysical researches.

During a recent visit to the U.S.A. it has been my privilege to meet many of the American seismologists, and to learn at first hand of the large amount of important work that is being carried on there. I wish to express to Lt.-Col. Tillotson my indebtedness for the way in which he has ungrudgingly taken on the additional work entailed by my absence, and in particular for compiling so much of the present Report.

R. STONELEY, *Chairman.*

MR. J. J. SHAW, C.B.E.

By Ernest Tillotson (reprinted from *Nature*, **161**, 920, by the kind permission of the Editors).

The death on May 23 of Mr. John Johnson Shaw at the age of seventy-four severs yet another link with the pioneers of the study of earthquakes in Great Britain.

J. J. Shaw was born at Gornal, near Dudley, educated at King Edward's School, Birmingham, and then apprenticed to an engineer. During the latter part of his engineering studies, he designed some gas and some steam pumps, and although he soon forsook his engineering to become a pawnbroker, he never lost his love for engineering. It was in the year 1908 that he read a newspaper article on the recording of earthquakes, and this encouraged him to visit Dr. John Milne, who, having retired from his professorship at Tokyo Imperial University, had settled in the Isle of Wight and set up a seismological observatory there. John Milne and J. J. Shaw became friends, and Shaw, on returning home, set up his first seismograph, which included as components an old treacle tin as drum, a wheat straw as pointer and a driving mechanism taken from an old German clock costing 1*s.* 11*d.* This instrument recorded some violent, world-shaking earthquakes, including the Messina earthquake of December 28, 1908 ; and with this early success and John Milne's encouragement, Shaw set about improving his instrument. The task became a life study, and in each Milne-Shaw seismograph made under Shaw's personal supervision some improvement on the previous one was embodied. Milne-Shaw seismographs are now working in many observatories throughout the world and are excellent for recording strong distant earthquakes.

Microseisms are now thought to be largely due to storms at sea. They gave ever-recurring trouble to the early observers, and Shaw suggested that data concerning them could best be obtained by the use of the tripartite seismograph station (British Association Seismological Committee Report, 1920), a method which in the hands of Father J. E. Ramírez at St. Louis, U.S.A., and later workers has given such good results.

Shaw, like John Milne, never lost an opportunity to make a friend for seismology. He fitted an electric bell to the seismograph system at his home in West Bromwich, so that he could be ready with instrumental results when any newspaper reporter rang him up about an earthquake. Reporters were often surprised at his perpetual cheerfulness over the telephone at any time of the day or night, and at the fact that his seismograph and his reference files often gave earlier information than their own telephone systems. A few years before the Second World War, Shaw was particularly pleased to set up one of his instruments in Selfridge's Store in London, so that any passer-by could see an earthquake being recorded should one occur at the instant he happened to be near the instrument. This instrument was suspended from one of the main structural steel pillars of the building, and since the steel went deep into the ground the pendulum recorded waves from distant earthquakes but was unaffected by street traffic or the movement of people in the store. This instrument is now in the Science Museum at South Kensington.

Shaw first became a member of the British Association Seismological Committee in 1914, probably having been proposed by his friend John Milne just prior to the latter's death in

July 1913. John Milne had been honorary secretary of the Committee for many years, and Prof. J. Perry had taken over the duties of secretary as a temporary measure on John Milne's death. At Manchester on September 8, 1915, Prof. Perry resigned the secretaryship and J. J. Shaw took over. He continued as honorary secretary until July 26, 1946, and was a member of the Committee until his death. As a member of the Seismological Committee of the British Section of the International Union of Geodesy and Geophysics, J. J. Shaw took part in many international meetings and established a world-wide reputation as an instrumental seismologist. He was also a popular scientific lecturer of considerable renown in the Birmingham district, having an infectious enthusiasm for popular science in general and instrumental seismology in particular ; being a kindly, forthright man, he made many friends. He was made C.B.E. in 1931, and awarded an honorary M.Sc. by the University of Birmingham a year later.

Mr. Shaw had suffered from knee trouble for some years, and on May 22 one leg was amputated ; the operation was successful, but he had a relapse and died the next day. He will be missed by many people not only in his home town and district, but also by a wide circle of friends and acquaintances throughout the world. His son, Mr. Harold V. Shaw, is expected to continue the observatory.

Meeting of Committee.—The Committee met in the Training College, Dundee, on Friday, August 29, 1947, at 12 noon.

The report of the Committee was discussed and approved.

The recording of earthquakes and tremors at Comrie and the availability of some person to interpret the seismograms obtained at Edinburgh were discussed.

The Chairman consented to write to the Director of the Royal Observatory, Hong Kong, with regard to the re-establishment of the seismograph station there.

The Gray-Milne Fund

During the present year the Trust Income received was the same as last year. After full discussion with the Committee of Section A at Dundee it was considered to be fully within the terms of the Trust to make a non-recurrent payment to the *International Seismological Summary* to help tide over a period of stringency between the expenditure of its grant from the Treasury and the receipt of the Unesco grant. The sum of £100 was accordingly paid over to Prof. H. Jeffreys for this purpose. No payment has been made during the year for the publication of tables or memoirs ; such payments are likely to arise in the near future, and it is considered advisable that part of the balance should be invested temporarily.

Gray-Milne Fund

	£ s. d.		£ s. d.
Balance, July 1, 1947 . .	505 17 5	Grant to *I.S.S.* . . .	100 0 0
Trust Income . . .	80 14 10	Postage and Printing . .	7 1 8
		Maintenance of Shock Recorder	5 0 0
		Balance, June 30, 1948 .	474 10 7
	£586 12 3		£586 12 3

International

The first post-war conference of the International Seismological Association was held at Strasbourg in July 1947 on the invitation of the University of Strasbourg ; the numbers attending were necessarily restricted. Much useful work was accomplished in preparation for the forthcoming meeting of the I.G.G.U. at Oslo in August 1948. The delegates from Great Britain were Prof. H. Jeffreys and Dr. R. Stoneley.

The former Secretary of the International Seismological Association, the late Prof. Edmond Rothé, has been succeeded by his son, Jean P. Rothé, both as Professor of Geophysics in the University of Strasbourg and as Secretary of the I.S.A., and this Committee welcomes wholeheartedly the continuation of the close and cordial relationship that has traditionally existed between French and British seismologists.

This Committee notes with pleasure that Unesco has continued for 1948 the grant of £3,000 made to the *I.S.S.* in 1947.

International Seismological Summary

By J. S. Hughes

The *International Seismological Summary* has continued at Kew, having now been housed at the observatory for eighteen months. Through the courtesy of the Director of the Meteorological Office, the two huts placed at its disposal in December 1946 are still available and the preparation of the work is being carried on. There is a staff of three, Mrs. Lofting having temporarily taken the place of Miss Naish who left at the end of 1947.

The production of 1935, 1936 has been completed. The issue of January-February-March quarter for 1937 is expected very soon, also the completion of the bound volumes for 1936. Manuscript for 1937 is compiled to the third week of September of that year and the printers are dealing with manuscript for the April-May-June quarter.

The past year has seen the change over from the normal geographic co-ordinates for the positions of the observing stations as a basis for the estimate of travel-times to that of geocentric direction cosines. The advantages of this have been explained elsewhere and the long-contemplated step of their introduction into the *I.S.S.* has now been taken. Such change means that no distances calculated for epicentres used before 1937 can be used for preliminary epicentres. The slowing up of work, now that the new system is well in hand, is, however, probably inappreciable.

Instruments

The instruments belonging to the Committee are located, as stated in last year's report, as follows :—

Milne-Shaw Seismograph, No.				1.	Downe, Kent.
,,	,,	,,	,,	3.	Edinburgh.
,,	,,	,,	,,	4.	Downe, Kent.
,,	,,	,,	,,	6.	Capetown.
,,	,,	,,	,,	27.	Perth, W.A.
,,	,,	,,	,,	63.	Suva, Fiji.
Seconds Regulator Clock					Suva, Fiji.
Jagger Shock Recorder					Comrie.

It is regretted that owing to shortage of staff, recording at Edinburgh was suspended during the past year.

It is hoped that the recording at Stonyhurst College Observatory is only temporarily suspended.

The British Earthquake in East Anglia on May 28, 1948 at 17h. 02½m. G.M.T.

By A. W. Lee

Recently Mr. L. L. Alexander of the Meteorological Office, Mildenhall, forwarded a note on the British Earthquake on May 28, 1948, at 17h. 02½m. G.M.T. This note will be published in the *Meteorological Magazine.*

The earthquake was felt over a considerable region of Norfolk, Suffolk and Cambridgeshire, but was accompanied by no appreciable damage.

It was recorded by the Kew Seismographs, both short period and Galitzin, the Pg occurring at 17h. 02m. 53s., G.M.T., and the Sg 14 seconds later ; the distance from Kew was therefore about 120 Km.

Milne-Shaw Seismographs at Downe House, Downe, Kent

By Dr. O. J. R. Howarth

These seismographs were removed from the University Observatory, Oxford, to Down House last year (1947). Here they were assembled by Miss E. F. Bellamy, in the basement of the house, on a pier constructed by Mr. Sydney Robinson, one of the Association's staff, who has since kept the instruments running and develops the records. The necessary bearings N-S and E-W were obtained with the help of Major Watson, engineer and surveyor to the Orpington Urban District Council, who kindly sent two of his assistants to determine them. After a period of trial (not unmingled with error) the instruments have been regularly at work since November 1, 1947, except for occasional stoppages of one or other of them for a day or two when adjustments have been necessary, and for the period February 19–27, 1948, when extremely cold weather and gales, together with a stoppage of the central heating in the house, threw the records into such disorder that they were practically useless. The instruments had also been out of action on February 16–18, during which time Messrs. Hughes

and Lawrence came from Kew and kindly checked the calibration. Only one stoppage (February 18) has as yet caused us wholly to miss any major tremor.

We at Down House are not competent properly to interpret the records, and are therefore incapable of issuing bulletins such as those issued from Kew and Durham. We receive these, thanks to Col. Tillotson's instigation, as also the preliminary notices of epicentres circulated by the United States Coast and Geodetic Survey. We have made a comparison of them with our own records for the six months January–June, 1948, to the extent of determining how far our records agree with them in showing tremors and their times. This comparison is summarised as follows :

During the period, we received 62 preliminary notices from U.S.C.G.S. Of the tremors so notified, we have failed to trace 21 in our records. In the monthly returns from Kew, 148 tremors were noted : we fail to trace 77 of them. Durham noted 48 : of these, we do not trace 5, but there are upwards of 20 in our records which do not appear in those of Durham.

Of the 71 Kew records which we also record, only 24 of ours coincide, exactly or within a minute, as to the time of starting. In all the rest, our starting times (so far as we are capable of distinguishing them) are later than those of Kew by periods varying from one to 51 minutes and averaging about 17 minutes. The same condition is found still more marked in regard to the length of time over which shocks are recorded. Our recordings appear usually to cease before—in many instances long before—those made at Kew. The suggestion which, subject to correction, presents itself to us is that the Milne-Shaw instruments are materially less sensitive than the Galitzins at Kew.

A large proportion of the movements recorded at Kew are small and of short duration. We only occasionally record these. In a few cases such Kew records are indicated as doubtful. In two of them—0048 hrs. on April 8 and 0701 hrs. on May 20—our records appear, though not with certainty, to confirm.

We note among our records the following which do not appear in those of Kew and Durham, and are not associated with preliminary notices from U.S.C.G.S. :—

April 12,	0957 hrs. (doubtful).
May 3,	1447–1454 hrs. (doubtful).
May 22,	2048–2127 hrs.
May 23,	0957–1005 hrs.
May 31,	1703 hrs. (doubtful).
June 19,	1911–1919 hrs.

In many of our records, especially in winter, microseisms obscure the readings of other tremors. The curator (Dr. Howarth) was kindly allowed by Dr. G. E. R. Deacon, F.R.S., to see the work on microseisms at the Admiralty Research Laboratory, Teddington, and he has subsequently sent Dr. Deacon notes of the periods during which microseisms have appeared most prominently in the Down records. It is not known whether these notes are of use.

Certain other movements common in our records to both instruments simultaneously have not as yet been accounted for by us.

Many of our records, compared with others the Curator has seen, are technically far from perfect. This, coupled with our ignorance in reading them, leads to the hope that they should, if possible, receive expert interpretation and criticism, in order that it might be decided whether it be worth while to continue the station.

Seismological Work of the Department of Geodesy and Geophysics, Cambridge, 1947–48

By P. L. Willmore

1. *Theoretical Investigation.*

Prof. E. R. Lapwood has examined the diffraction effects at the surface of a semi-infinite homogeneous elastic medium after a pulse has been emitted by a buried line-source. It is shown that, at distances large compared with the depth of the source, the disturbance at the time of arrival of the direct S-pulse differs from that at the arrival of the P-pulse in being smudged or blunted.

2. *Long-range explosion seismology.*

Mr. P. L. Willmore spent several months in Germany, arranging for seismological observations to be made on the tremors from the Heligoland explosion of April 18, 1947. Observations were made by portable seismographs in Germany, Holland and Denmark and by ships in the North Sea. The tremors were also recorded by observatory seismographs in Belgium, France, England, Czechoslovakia and Switzerland. The results confirm the high

velocity for Pn (8·18 Km./sec.) but reveal significant local variations in the apparent velocity of Pg. P* and the transverse waves were not well recorded.

3. *The Investigation of Microseisms.*

Mr. M. N. Hill and Mr. Wilson are investigating the origin of the microseismic background in various ranges of frequency. The work has so far been restricted to frequencies greater than 8 cycles per second, where it appears that most of the disturbance is man-made. It is hoped to extend the investigation to longer periods as the apparatus is developed.

4. *Seismic work at Sea.*

In February 1947, Mr. M. N. Hill and Mr. P. L. Willmore carried out preliminary experiments to show that hydrophones suspended in the water would give satisfactory records of seismic waves in the bottom. Later in the year, the technique was extended by attaching the hydrophone to a radio transmitter mounted in a buoy. It was then possible to fire a charge in the water, and to record the arrival of the seismic waves over a distance of several miles by a single ship. Development of this method is being continued by Mr. M. N. Hill. Shipping and other facilities for the work have been provided by the Marine Biological Association at Plymouth.

5. *Short-range Seismology on Land.*

Mr. J. A. F. Gerrard and Mr. H. P. Coster have investigated the possible existence of a drift-filled outlet from Windermere through the Cartmel Valley, and found that no such outlet exists. They have also applied the seismic method to study the former course of the Rheidol river through the now dry valley running southward to the east of Aberystwyth. Mr. J. A. F. Gerrard and Mr. Wilson did some work in Cumberland for the United Steel Companies.

6. *Seismographs.*

A set of fifteen moving coil seismographs have been constructed to Mr. P. L. Willmore's design. They have a substantially constant response to ground velocity over the frequency range from 2 to 25 cycles per second, with a maximum sensitivity of 5000 cms. per cm. per sec. It is hoped to use the instruments to assist in the investigation of the earth tremors in the Witwatersrand region of South Africa, and of those from forthcoming ammunition explosions in New Guinea, and in the West Indies.

Mr. M. N. Hill has designed a long-period inductance bridge seismograph, capable of driving a standard pen-recorder. The instrument is fitted with an electronic stabilising device to eliminate zero drift.

Publications.

Coster, H. P. and Gerrard, J. A. F. 'Seismic Investigation of the Outflow of Windermere,' *Geol. Mag.*, **84**, 224, 1947. 'A Seismic Investigation of the History of the River Rheidol in Cardiganshire,' *Geol. Mag.*, **84**, No. 6, 360, 1947.

Hill, M. N. and Willmore, P. L. 'Marine Seismic Prospecting,' *Nature*, **159**, 207, May 1947.

Lapwood, E. R. *The Disturbances due to a Line Source in a Semi-Infinite Elastic Medium*—in course of publication.

Willmore, P. L. 'The Heligoland Explosion,' *Nature*, **160**, 350, 1937.

Report of Seismic Work on the North German Explosions, 1946–47

By P. L. Willmore

In the autumn of 1946, 10 stacks of bombs, each containing up to 40 tons of explosive, were detonated near Soltau. These were followed on April 18, 1947, by the explosion of nearly 4,000 tons of ammunition on Heligoland. The Surplus Explosives Committee of the Royal Society recommended that observations should be made on the tremors produced by the explosions. The work in Germany was planned in collaboration with the Control Commission and the military authorities concerned, and was carried out mainly by field teams from the Geophysical Institutes at Göttingen and Celle. The Heligoland tremors were also recorded by stations in Denmark, Holland, Belgium, France and Switzerland and by two ships in the North Sea. A paper giving the complete results, and a report on the discussion at the Royal Society are in the press. Details of the organisation have already been described. (1)

Travel times were observed at distances up to 50 Km. from Soltau and between 50 and 1,000 Km. from Heligoland. At the near stations, delays of about one-third of a second were introduced by the presence of thick unconsolidated sediments. These were corrected as far as

possible by using the travel-time chart for North Germany (2) and the data given by Nørlund and Brockamp (3) for Denmark. The profiles described in the latter paper also showed that the velocity in the basement rocks was higher than under Soltau, and suggested that the Danish Stations at Møgeltonder and Kolding should read about 0·35 sec. earlier than the German ones. The observed residuals were — 1·0 and 0·83 sec. respectively. The presence of deep sedimentary rocks under the Alps was confirmed by a positive residual of 0·6 sec. at Chur.

Comparison of the shorter profiles showed that the velocity of the first arrivals between 25 and 106 Km. varied between 5·6 and 6·65 Km./sec., and suggested that the composition of the granitic layer varied sharply from place to place. On averaging the results from groups of stations within regions 50 Km. in extent it was found that a mean velocity of 6·1 Km./sec. could be assigned to Pg over the first 200 Km. At greater distances, the mean velocity was 5·1 Km./sec., but the distribution of residuals suggested that the arrivals may have been due to separate phases with velocities of 4·9 and 5·5 Km./sec. respectively. Pn was very clearly shown, and was followed by a wave which appeared to be propagated through the ultrabasic, after suffering reflection from the surface at one point in its path. Charlier (4) reports the same phase, but suggests that it is propagated through a separate layer. There was no conclusive evidence for the existence of P*.

Transverse waves were not well recorded, although disturbances which might correspond to Sn, Sg and R were received at a few stations. The apparent time of starting of Sn was before that of Pn, but this effect might conceivably occur if the S waves were generated by the process of refraction from primitive P waves. On testing the results to discover whether they were significantly grouped about the lines, Sn was found to be the most reliable of the three. The groups of arrivals representing Sg and R were not satisfactorily significant, but three of the arrivals corresponding to the latter phase were particularly strong ones.

The characteristics of the phases are given in the Table, which also includes figures for the thicknesses of the three assumed layers. The single figure given for the sedimentary is somewhat arbitrary, as velocities ranging from 1·6 to 5·4 Km./sec. have been observed within a few kilometres of the surface. The correction for the surface layers effectively replaces the softest materials by rock with a velocity of 4 Km./sec. and the value given is a rough average for this and the harder materials. The complete results indicate that the properties of the ultrabasic layer are remarkably uniform, and confirm the high velocity of Pn found from the Burton-on-Trent Explosion (5). Variations in the velocity of Pg are more significant, and it is suggested that they should be considered in future Near Earthquake studies.

Phase	Velocity	Starting Time	Thickness	Standard Deviation of one Observation.
Sedimentary P wave .	4·4 Km./sec.	0	9·01 ± 1 Km.	—
Pg (Near Stations) ·	6·06 ± 0·09	2·8 ± 0·27	17·4 ± 2 Km.	0·16 secs. on regional means.
Pg (Distant Stations) ·	4·9 — 5·5	—	—	3 secs. for 1 layer 0·50 and 0·86 for 2 layers.
Pn · · ·	8·18 ± 0·014	7·37 ± 0·1	—	0·19 sec.
Sn · · ·	4·36 ± 0·06	2·8 ± 1·3	—	0·43 sec.
R · · ·	3·05 ± 0·1	4·6 ± 6	—	3·6 sec.

The total energy was computed from the amplitudes and frequencies observed at 8 stations, on the alternative hypotheses that the motion was confined to a depth of 15 Km. or that it was spread evenly over a hemispherical wave front. The latter hypothesis gave the more uniform results and led to a value of 10^{17} ergs for the whole explosion. The hemispherical theory was supported by the fact that the amplitude of the early P arrivals was often the greatest on the record. Measurements on the crater showed that $1·5 \times 10^{18}$ ergs were expended in moving the rock above the charge, whilst the total thermal energy of the explosive

was $1 \cdot 3 \times 10^{20}$ ergs. On introducing the fact that the mass of rock was about 100 times that of the explosive, it was found that the top cover probably increased the momentum in the ground by a factor of 2 or 3 above the value for a surface explosion.

References.

(1) Willmore, P. L. : 1947, *Nature*, **160**, 360.
(2) *Geologisches Landesamt*, Hannover : 1947, Geotechnic Map. of N.W. Germany, 1 : 100,000.
(3) Nørlund, N. E., and Brockamp, B. : 1934, *Mem. Inst. Geod. de Danemark*. Series 3, **2**.
(4) Charlier, A. : 1947, *Pub. du Service Séismologique et Gravimétrique, Uccle*, Serie S, Nos. 2 and 3.
(5) Jeffreys, H. : 1947, *M.N.R.A.S.*, **5**, No. 5.

The Generation of Microseisms

By Dr. G. E. R. Deacon, F.R.S.

Work at the Admiralty Research Laboratory seems to throw some light on the origin of microseisms.

They cannot be generated in deep water by simple progressive gravity waves of Stokes's type because of the rapid attenuation of the pressure variations with depth, and because of the short wavelength of water waves compared with seismic waves of the same frequency. But Miche has shown that in a stationary wave motion there are second-order pressure variations (proportional to the square of the wave height) of twice the wave frequency and not attenuated to zero in infinite depth. A simple demonstration of Miche's result has been given, and it has been shown that this type of pressure fluctuation occurs when there is interference between wave-groups of the same frequency travelling in opposite directions. Assuming incompressibility the mean pressure beneath such interfering wave trains fluctuates with a frequency double that of each wave train and with an amplitude proportional to the product of the wave amplitudes. This interference may arise in the neighbourhood of a fast-moving depression over the sea, and in coastal regions where energy is being reflected from the shore. In such areas, whether deep or shallow, pressure variations capable of generating microseisms are transmitted to the sea bed.

The theory explains why storms of equal intensity do not necessarily generate microseisms of the same magnitude, and it suggests a definite two to one relationship between the periods of the waves and microseisms which has been confirmed by observations. Visual comparison between records of wave height on the coast of Cornwall and microseisms at Kew appeared to show that the microseisms are caused mainly by waves in the coastal region, but it was argued that the effect of waves in deep water at some distance from the coast would generally be obscured by the effect of waves in the coastal region, and if there is a close relationship between the periods of the waves and microseisms it should be possible to distinguish between microseisms generated in the near and distant areas provided there is an appreciable difference between the dominant wave periods in the two areas. Such a distinction has been made by submitting simultaneous records of waves and microseisms to frequency analysis. Two examples were chosen in which there was a single depression 1000–1200 miles from the west coast of the British Isles, and in addition to microseisms of half the period of the coastal waves the microseism spectra showed definite bands of half the period of the waves in the distant storms. These could be detected in the Kew records some 30 hours before the swell from the distant storms reached the coast.

In one of the examples the appearance of a band of microseisms of half the distant wave period is not regarded as conclusive evidence that the microseisms were generated in deep water, because the storm was not far from the shallow water off Greenland, but in the second example—a depression moving rapidly over deep water north of the Azores—it appears safe to conclude that they were generated in deep water. An estimate of the order of magnitude of the microseisms shows that the theoretical amplitudes are not in disagreement with those observed.

Reappointment

The Committee desires to be reappointed, without a grant.

Postscript.—The Council of the Association have reappointed the Committee with the following changes in membership :

Retired : Prof. E. C. Bullard, F.R.S.

New Members : Mr. B. C. Browne, Mr. M. N. Hill, Mr. E. N. Lawrence, Dr. G. D. Robinson and Mr. H. V. Shaw.

NON-LINEAR VIBRATIONS

REPORT PREPARED BY

DR. MARY L. CARTWRIGHT, F.R.S.

WITH THE ASSISTANCE OF PROF. E. T. COPSON AND PROF. J. GREIG

CONTENTS

SECTION	PAGE
1 INTRODUCTION	64
2 GENERAL METHODS	
I. ELEMENTARY REAL VARIABLE	64
II. STEP-BY-STEP NUMERICAL METHODS	65
III. OTHER NUMERICAL METHODS	65
IV. CLASSICAL METHODS OF APPROXIMATION	65
V. APPROXIMATIONS WITH LARGE NON-LINEAR TERMS	65
VI. TOPOLOGICAL METHODS	65
3 PROBLEMS OF NON-LINEAR VIBRATIONS	66
4 THE PHYSICAL SIDE	67
5 STANDARDS OF RIGOUR	67
6 SUBHARMONICS	68
7 RELAXATION OSCILLATIONS	68
8 NUMERICAL AND GRAPHICAL ANALYSER SOLUTIONS	68
9 TOPOLOGICAL METHODS AND PURE THEORY	69
10 PARAMETRIC EXCITATION	69
11 GENERAL BACKGROUND	69
12 MISCELLANEOUS RECENT WORK	69
BIBLIOGRAPHY AND NAME INDEX	69

SECTION 1

INTRODUCTION

THE title is chosen in preference to 'Non-Linear Mechanics' on which we were asked to report because the latter covers nearly the whole of mechanics, and would embrace far too wide a field. Of recent years in Russia, and also in the U.S.A., Non-Linear Mechanics has been used to refer to the study of non-linear vibrations or oscillations of a particular type—whose early development is due mainly to Appleton, Greaves, and van der Pol. The type occurs in connection with ordinary differential equations in certain electrical and mechanical problems, especially in radio work, and we shall make these the main subject of the report. We use the word 'vibration' to cover periodic or almost-periodic solutions, and we include what are called relaxation oscillations which may be represented by two or more different differential equations over different parts of the period, and we make some references to discussions of transients in electric circuits. According to Minorsky the Russian literature alone up to 1940 comprises 2,000 pages, and there has been much written by the Russians since then, and much written outside Russia. We therefore obviously could not read more than a small part, and our selection of references may sometimes seem arbitrary. We give references to works containing summaries and accounts of earlier work, but since these are often not easily available, we occasionally duplicate. Further we give references to a few of the most fundamental papers and books covered by the summaries, besides others not covered by the summaries, but anyone studying the subject seriously should look up to the relevant references in the summaries to which we refer.

We should like to express our thanks to all those who have helped us in the preparation of this report, especially to Prof. Hartree and Dr. P. Nicolson for advice in connection with Sections 2.II and 2.III.

SECTION 2

GENERAL METHODS

Before discussing the special non-linear vibrations, we summarise the most important methods for attacking any non-linear problem, assuming first that the physical phenomenon has been expressed correctly by a differential equation, which may of course be the fundamental difficulty.

I. *Elementary real variable methods.*—These involve direct application of the elementary methods of the theory of functions of a real variable to the differential equation in order to determine the general behaviour of the

solution, whether it tends to infinity or to a finite limit as the independent variable $t \to \infty$, whether the solution changes sign and so on. These methods can be very short and completely rigorous, and cover large ranges of values of parameters ; but they are elementary only in the sense of not appealing to complicated known results, and seem to be rather delicate and difficult to initiate. A development of the technique seems desirable, but it is not likely to give an accurate solution for all values of the variables.

II. *Step-by-step numerical methods.*—The most generally effective method of finding solutions of differential equations with *given initial conditions* is step-by-step numerical integration from those conditions. This may be sometimes done more conveniently by the help of a differential analyser (which is sometimes described as an analogue machine), or by an automatic digital machine such as ENIAC. The most modern type of differential analyser operates by electronic methods ; the older types are mechanically constructed. Both types can be constructed to work within 1 per cent. accuracy without very great expense, but if greater accuracy is required the construction of the machine becomes very costly. The setting of the machine takes time, but once it is set for an equation, a large number of solutions can be run off fairly quickly ; on the other hand, if less than, say, 10 solutions are required, it is probably quicker not to use the differential analyser. The methods of numerical integration have been much improved by Hartree and his school, and many minor improvements in technique have been developed which are not included in any published account. Graphical methods may also be useful where great accuracy is not required. A discussion of numerical methods with special reference to transients in electric circuits is given in ' Electric Circuits ' by the Electrical Engineering Staff of the Massachusetts Institute of Technology.

III. *Other numerical methods.*—If a solution is required satisfying some other condition than given *initial* values—for example, if it is periodic or if values are given at two points—the step-by-step methods fail. It is possible to try with some set of initial conditions, and readjust until the other conditions are nearly satisfied, but unless the first set is sufficiently near to the set satisfied by the required solution, it is possible to miss a periodic solution entirely, and in any case the method is long. If the motion is damped sufficiently, it might be expected that by continuing the step-by-step method sufficiently far, a good approximation to the final steady state might be obtained ; but this is not necessarily so, and here again it is necessary to know something about the possible steady states. Relaxation methods have so far been applied mainly to linear problems ; it seems possible to extend them to non-linear problems, but they are very laborious. There is also a method of treating linear problems by minimising quadratic forms which might possibly be generalised. This is described in America as the method of steepest descents, but it has nothing to do with the method of finding asymptotic expansions by steepest descents.

IV. *Classical methods of approximation.*—Under this heading we group the analytical methods available when the non-linear terms are small or the differential equation does not vary much from some well-known case which has been solved satisfactorily. The literature is very considerable and includes a large part of classical dynamics ; in particular the work of Poincaré, Lindstedt, and Liapounov is relevant. Keller has given a summary of such methods with special reference to electrical engineering, including the translation of the problem into one of integral equations, but Keller's summary contains practically no references to Russian work which is extensive.

A solution with given initial values can often be expanded in a convergent series of powers of some small parameter by Poincaré's theory ; but the steady state solution varies with that parameter and so it does not usually have fixed initial values. The series obtained are sometimes asymptotic series which are not convergent, as is evident from the way in which steady state solutions sometimes become unstable and vanish when a parameter is changed slightly.

V. *Approximations with large non-linear terms.*—The work by van der Pol, Liénard and le Corbeiller are perhaps the best known examples of such methods. The characteristic feature is that the terms of the differential equation which are important over one part of the period are different from those important over the rest, and of course the transition presents serious difficulties. In the physical problems relating to relaxation oscillations and certain cases of frequency demultiplication the actual differential equation may be different for different parts of the motion. The Russians developed a corresponding theory of discontinuous oscillations, treating the motion as represented by different equations over different parts of the motion, and Levinson and others have discussed the singular perturbation theory connected with discontinuous oscillations.

VI. *Topological methods.*—It is well known that the problem of establishing the existence of periodic solutions of a differential equation

is equivalent to the problem of establishing the existence of fixed points under certain types of transformation. The theory also covers corresponding theorems about almost-periodic solutions of differential equations. Birkhoff's work on Poincaré's Last Geometric Theorem is important for conservative systems, and Denjoy's work lies deep. The Russians use the topological point of view a good deal, and Levinson has developed the general theory with special reference to non-linear systems dissipative for large displacements. The theory of almost-periodic solutions is connected with the ergodic problem for which the literature is very extensive.

Section 3

Problems of Non-Linear Vibrations

We now restrict ourselves to non-linear vibrations. The following are a few examples. In radio work the differential equation of a triode oscillator can be written :

(1)
$$\frac{d^2v}{dt^2}+\frac{1}{C}\frac{d}{dt}\left\{\frac{v}{R}+\psi(v)\right\}+\frac{1}{LC}v=\omega_1^2\,E\sin\omega_1 t,$$
where $\psi(v)$ is usually assumed to be a cubic polynomial. By suitable changes of variable when $\psi(v)$ is an odd cubic polynomial it can be reduced to van der Pol's equation with forcing term :

(2) $\ddot{y}-k(1-y^2)\dot{y}+y=b\lambda k\sin\lambda t.$

If $b=0$, and we integrate and put $x=\int y\,dt$, we have Rayleigh's equation

(3) $\qquad \ddot{x}-(A+B\dot{x}^2)\dot{x}+x=0,$

which is connected with acoustical phenomena and also with ballast tanks in ships.

Problems with non-linear restoring forces give rise to equations of the form

(4) $\qquad \ddot{y}+k\dot{y}+g(y)=b\sin\lambda t$

where $g(y)/y>0$, $k\geq 0$. The equation of hunting connected with a synchronous motor is similar to (4) with a constant B on the right.

There are also mechanical problems with non-linear damping, known as Coulomb damping, different from the type in (2) ; and some problems of ferro-magnetism involve equations of the form

(5) $\qquad \ddot{x}+f(x)\dot{x}+g(x)=b\sin\lambda t,$

where $f(x)$ is approximately a polynomial of the fourth degree and $g(x)$ approximately a polynomial of the fifth degree such that $f(x_0)>0$ and $xg(x)>0$ for all x.

Some acoustical and electrical problems involve non-linear terms multiplied by periodic functions of t such as

(6) $\qquad \ddot{y}+2\gamma\dot{y}=\varepsilon I(y)\cos t$

where $I(y)$ is a cubic polynomial.

In (1) (2) when $b=0$ and (3) the amplitude of the steady state oscillation is fixed by the coefficient of $\dot{x}$; and, so long as k is small, the natural frequency of (2) is nearly $1/(2\pi)$; but in (4) the natural frequency when $k=0$ and $b=0$ varies with the amplitude, and so the difficulties in (2) and (4) are of a different type. Both types of difficulty may of course occur together, and with the complication of periodically varying parameters as in (6).

A system with two degrees of freedom represented by a pair of equations of type somewhat similar to (2) was discussed by van der Pol, and more general systems of a more or less similar kind have since been discussed by various Russian authors. Levinson has discussed a third order differential equation representing a valve oscillator, and Gladwin has discussed types of valve oscillator corresponding to a third order differential equation which presents some new features, viz. the shift of the working point is important in the determination of the amplitude of the steady state ; the non-linear functions have discontinuous first or second derivatives and polynomial approximations are not satisfactory, in spite of the fact that the higher harmonics are negligible ; the amplitude of the oscillation is determined by a balance between two unsymmetrical functions which correspond roughly to the restoring force and damping, and not by a balance of positive and negative damping as in (2) ; there is sometimes a periodic instability known as 'squegging.'

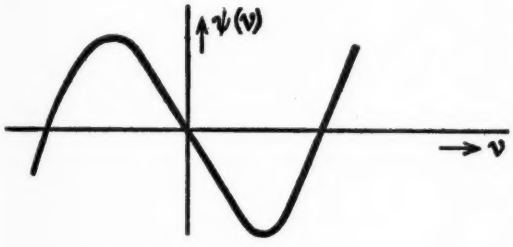
In radio work the emphasis is on the steady state oscillation, the problem is to find the values of the parameters for which it is periodic or almost-periodic, and how the frequency or frequencies vary with the parameters of the circuit. The frequency seems the most difficult property of the solution to determine analytically ; but none of these problems is easily adapted for attack by methods 2.I and 2.II, and the radio engineer who wants to know the effect of changing parameters does not find it worth while to settle down to the laborious methods of 2.III. Hence a large literature has come into existence dealing with these problems, often by very casual methods. In many cases the oscillation is known to be sinusoidal, and the differential equation can be written in a form in which the non-linear terms are small so that methods 2.IV bulk large ; but in some cases methods 2.V are needed. In other electrical and mechanical problems such as those where a qualitative explanation of the peculiar resonance features and sub-harmonics due to non-linear restoring forces is needed, similar methods are used ; but in the study of transients and build-up of oscillations the methods of 2.II are often more useful than analytical methods.

Section 4

The Physical Side

The non-linear differential equations themselves are hard to solve, but in some cases it has eventually been established that the differential equation did not represent the physical system accurately. The process of approximation begins with the formulation of the differential equation, and an elaborate solution is useless if the initial approximation is too crude. Further the fundamental difficulty may be in the formulation of the equation. On the other hand, some papers which are almost entirely concerned with the physical phenomena and which do not expressly mention the differential equation can be very suggestive as to the possible form of steady state solutions of differential equations; but we cannot cover all types of non-linear effects.

A typical difficulty of approximation is encountered in equation 3 (1). The function $\psi(v)$ is roughly of the form :



Since, for $E = 0$, the system is known to perform oscillations approximately of the form $a \sin t$, and higher terms than those of the third order in the Fourier series can certainly be neglected, it is natural to assume that $\psi(v)$ is of the form $-\alpha v + \beta v^2 + \gamma v^3$ where $\alpha > 0$, $\gamma > 0$. But although this approximation may represent $\psi(v)$ with sufficient accuracy to obtain the value of the frequency and amplitude of the periodic motion for a *given* set of parameters L,R,C, if R changes, the amplitude changes; what is the best approximation over a small range is not likely to be the best approximation over a large range. So for the purpose of studying the change of amplitude or frequency with R, there is a hidden difficulty of finding the best approximation. Gladwin works with Fourier coefficients obtained directly from the non-linear functions.

Section 5

Standards of Rigour

The behaviour of solutions of equations like 3 (1) and 3 (4) is sometimes distinctly odd, and there are many pitfalls for those who use approximations carelessly. The discussions which are mainly physical are very often fundamentally sound mathematically, but there is much work on the subject which is of poor quality. Some is neither sound physics nor sound mathematics. Some is too elaborate and complicated to be of much practical use, and lacks the basis of rigour needed for pure theory, and there is much inadequate repetition of work done better by earlier writers. The fact that we include a reference to a certain work is no guarantee that it does not contain serious errors. For the same paper may contain something of positive value together with careless, misleading or even quite wrong work, and we could not possibly check all details. For instance, Pedersen's work was important in drawing attention to the possibility of subharmonics, but his elaborate Fourier series seem to be of little value.

The cases in which one parameter is small and another is near some critical value corresponding to some form of resonance give rise to many complications which are ignored, or passed over much too rapidly in some of the comprehensive general treatments (such as that of Kryloff and Bogoliuboff) which profess to cover all cases. The details of such treatments need careful verification before the results are used. For instance, results are stated about amplitudes for subharmonic resonance without showing what happens on either side of resonance in a neighbourhood which must be within the critical range of the detuning parameter.

The limits of validity of some of the more physical work is not always very clear. For instance, it is sometimes stated that the equation

$$\ddot{v} - (\alpha + \beta v - \gamma v^2)\dot{v} + \omega^2 v = 0$$

has a stable sinusoidal solution of the form $v = a \sin \omega t$ approximately where $a = (\alpha/\gamma)^{\frac{1}{2}}$, provided that α/ω is sufficiently small, and that the term $\beta v\dot{v}$ can be neglected. This is true up to a point, but not without some reservation. If β is *sufficiently* large, the term $\beta v\dot{v}$ may produce waves nearly of the sawtooth type, and make stable sinusoidal solutions impossible.

However, once the limits of validity are determined, the task of justifying the physical work in many cases should not be difficult to a competent analyst.

Unfortunately it is extremely difficult to give any reference to a simple, satisfactory, and easily accessible exposition of a sound method which is generally applicable. The method of Appleton and Greaves is satisfactory for sinusoidal solutions of equations like 3 (4) and 3 (5), but only for $b = 0$. The ideas of Poincaré and Liapounov can be used as in Minorsky, but it is not easy to extract

precisely what is needed from the general results of Minorsky. The lectures published by Brown University and New York Institute of Mathematics in typescript treat the subject more from the pure mathematician's point of view.

The Russian authors whose work is summarised by Minorsky handle the general theory of Poincaré and Liapounov with facility and use a terminology involving expressions such as 'equivalent linearisation,' 'entrainment of frequency,' 'asynchronous excitation,' and 'parametric excitation.' Even the group headed by Mandelstam, and Papalexi, whose interests are mainly physical, appear to enjoy developing a general mathematical theory before concentrating on the particular cases relevant to their problem. In view of the difficulties mentioned in Section 4 of approximating to such functions as $\psi(v)$ in 3 (1) by polynomials, it seems waste of energy to elaborate in this way for the sake of the physical problem, and from a theoretical point of view many of the details need further investigation. In most Russian work the misprints are numerous and misleading. Minorsky's account is useful as a summary, but for reasons of space it omits much, including a good deal that the pure mathematician needs, and also a good deal of the physics. On the other hand, it includes some very general formal calculations which are rather forbidding. In spite of this it cannot be denied that the Russians have done much valuable work ; the Moscow school mainly in connection with radio problems, and Kryloff and Bogoliuboff in general theory involving the use of deep theorems due to Liapounov and Denjoy.

Section 6

Subharmonics or Frequency Demultiplication

When equations such as 3 (2) and 3 (4) have solutions with period $2n\pi/\lambda$, where n is an integer greater than 1, we say that there are subharmonics, or in radio work that there is frequency demultiplication. In most cases in which this occurs the free period of the system without the forced oscillation is very nearly n times that of the forced oscillation. The phenomenon was discussed by Koga, Mandelstam and Papalexi for sinusoidal solutions of equations of type 3 (1) and by Pedersen, den Hartog and Mikina, and Baker for sinusoidal solutions of equations of type 3 (4). Van der Pol and van der Mark observed it in relaxation oscillations, and Theordorchik discussed this physical phenomenon. The mathematical side is interesting in the case of sinusoidal solutions ; and when the non-linear terms are large the theory presents new features. Cartwright and Littlewood have shown that the equation 3 (2) for certain values of b between 0 and $\frac{2}{3}$ may have subharmonics with periods $(2n-1)2\pi/\lambda$ and $(2n+1)2\pi/\lambda$, and these values of the periods may be considerably less than the period with $b=0$. Graphical solutions were obtained by Herr in a few cases.

Section 7

Relaxation Oscillations

The most important work on these has already been discussed in Section 2.V and Section 6. The term is very vague and is usually taken to cover almost all oscillations which are not sinusoidal, or nearly so ; it has nothing to do with relaxation methods of solving differential equations. It is possible that some people might describe the phenomena as being due to transients at regularly spaced intervals of time.

Section 8

Numerical and Graphical Solutions

Solutions of some of these equations have been obtained on the differential analyser or by other numerical methods. As we observed in Section 2.III it is possible, in the absence of some general idea of the theory, to miss finding the qualitative nature of the solutions when convergence is slow, when two different types of steady state lie close together, or when only a small set of initial values gives solutions converging to a particular steady state. In the latter case varying the parameters of the physical oscillating system may show the existence of solutions missed on the differential analyser.

The solutions by Brainerd and Weygandt cover a range of parameters appropriate to applications but are insufficient to throw light on the problem whether the equation

$$\ddot{x}-(\alpha+\beta x-\gamma x^2)\dot{x}+x=0$$

can have more than one stable periodic solution. The solutions by Herr are interesting, but do not show the existence of two subharmonics of different period for the same set of parameters which is now known, and was first suggested by the experiments of van der Pol and van der Mark on a system corresponding to a different equation. The results obtained for Section 3 (1) numerically by Rjasin did not determine the limits of occurrence of non-synchronised stable oscillation, and Gapanov seems to have obtained a result which would involve discontinuous behaviour which is inadmissible theoretically. Hartree's results cover a range appropriate to applications which is difficult to tackle by analytical methods, but they raise rather than settle theoretical problems.

Størmer obtained a remarkable collection of numerical solutions of the equations of motion of an electron on the field of a magnetic dipole, including many periodic orbits. He also made a large number of models in three dimensions showing various cases.

Section 9

Topological Methods and Pure Theory

When the non-linear differential equations representing vibrations are attacked from a purely theoretical point of view, especially when the non-linear terms are not necessarily small, a good deal of the interest lies in the interpretation of the results in the terms of the topology. Liénard, Levinson and Smith actually present their proofs in a rather topological form, and the work of Cartwright and Littlewood raises topological problems connected with the work of Birkhoff, Denjoy and Charpentier on fixed points, recurrent sets and rotation numbers.

The purely theoretical side of the work is developing rapidly, especially in Cambridge, Manchester, and in various universities in the U.S.A. A more or less popular account of some topological results has been given by Cartwright.

Section 10

Parametric Excitation

The Russians use this expression to denote excitation caused by variation of some parameter, and call it heteroparametric if the parameter varies explicitly with the time and autoparametric if the parameter depends on some physical quantity and varies implicitly with the time. The first type is connected with equations such as Mathieu's and Hill's which also arise in connection with stability as perturbation equations about a periodic solution.

Section 11

General Background

There is an account of the Poincaré-Bendixson theory of singular points and limit cycles in Bieberbach and in Lefschetz, and something about Liapounov's work in Goursat; the equations of Mathieu and Hill are discussed by McLachlan. The topological theory of fixed points in the plane is almost buried in the general combinatorial theory; but there is a simple fixed point theorem in Courant and Robbins' 'What is Mathematics?', and Newman's 'Topology of Plane Sets' provides the general background. Birkhoff's 'Dynamical Systems' contains his famous proof of Poincaré's Last Geometric Theorem, but Birkhoff's 'Surface Transformations' is more relevant to the special theory connected with non-linear vibrations.

Section 12

Miscellaneous Recent Work

Since 1943 *Mathematical Reviews* has had a section devoted to non-linear oscillations, and critical summaries of mathematical papers will be found there, including many not mentioned here. There have been two papers by Shohat on van der Pol's equation, and one by de Bruijn criticising Shohat's work. The Russians have written prolifically, especially on non-linear systems with several degrees of freedom, on the stability of regulating systems, on numbers of limit cycles near a vortex or foyer, and on other similar topics. Weyl's discussion of the theory of singular points of ordinary differential equations and Siegel's work on differential equations on a torus may be relevant to the foundations of the pure theory. On the physical side of the work of Tillman, Meuser and Weibel, Müller-Strobel, Tucker, and Wenke may be mentioned; mainly physical work is not usually included in *Mathematical Reviews*. Wenke discusses the equations

$$\ddot{x} + \frac{k}{m}\dot{x} + \frac{c}{m}(\lambda' - \alpha' \sin 2pt + \beta' x^2)x = 0,$$

$$\ddot{x} + 2\delta\dot{x} + \zeta^2 x - \beta_2' x^2 = \mathrm{P}' \sin(2pt - \epsilon_2),$$

and gives references to earlier work on them. Tillman obtains results in terms of Bessel functions. Meuser and Weibel discuss the equation

$$m\ddot{x} + c\dot{x} + k_1 x + k_2 x^3 = \mathrm{P} \sin(\pi\lambda t^2 + \alpha).$$

Tucker discusses the synchronisation of oscillators. Summaries of these and other papers on similar topics appear in *Science Abstracts*, but these summaries are much briefer and less critical than those in *Mathematical Reviews*.

References

SECT.

1 (i) B. van der Pol. A theory of the amplitude of free and forced triode vibrations. *Radio Review* (incorporated later with *Wireless World*), **1** (1920), 701–710.

(ii) E. V. Appleton. The automatic synchronization of triode oscillators, *Proc. Cambridge Phil. Soc.* **21** (1922), 231–248.

(iii) E. V. Appleton and W. M. H. Greaves. On the solution of the representative differential equation of the triode oscillator, *Phil. Mag.* **45** (1923), 401–414.

(iv) W. M. H. Greaves. On a certain family of periodic solutions of differential equations with an application to the triode oscillator, *Proc. Roy. Soc. A*, **103** (1923), 516–524.

(v) W. M. H. Greaves. On the stability of the periodic states of the triode oscillator, *Proc. Cambridge Phil. Soc.* **22** (1923), 16–23.

SECT.

(vi) E. V. APPLETON and B. VAN DER POL. On a type of oscillation-hysteresis in a simple triode oscillator, *Phil. Mag.* **43** (1922), 177–193.

(vii) E. V. APPLETON. On the anomalous behaviour of a vibration galvanometer, *Phil. Mag.* **47** (1924), 609–619.

(viii) C. DUFFING. *Erszwungene Schwingungen bei verändlicher Eigenfrequenz* (Braunschweig, 1918).

(ix) B. VAN DER POL. On relaxation oscillations, *Phil. Mag.* **2** (1926), 978–992.

(x) B. VAN DER POL. Forced oscillations in a circuit with non-linear resistance, *Phil. Mag.* **3** (1927), 65–80.

(xi) N. KRYLOFF and N. BOGOLIUBOFF Méthodes de la mécanique non-linéaires appliquées à l'étude des oscillations stationnaires. Monograph in Russian with summary in French (Kiev, 1934). *Ukrainska akad. nauk., Inst. mech. Report* 8.

(xii) N. KRYLOFF and N. BOGOLIUBOFF. *Introduction to non-linear mechanics*, trans. by S. Lefschetz, *Annals of Mathematics Studies*, No. 11, (Princeton, 1943), where further references will be found.

(xiii) N. KRYLOFF and N. BOGOLIUBOFF. Introduction à la mécanique non-linéaire : les méthodes approachées et asymptotiques, *Ukrainska akad. nauk., Inst. mech. Chaire de phys. math Annales*, in Russian, **1–2** (1937).

(xiv) L. MANDELSTAM, N. PAPALEXI, A. ANDRONOV, S. CHAIKIN and A. WITT. Exposés des recherches récentes sur les oscillations non-linéaires (in French), *Tech. Physics of U.S.S.R.* **2** (1935), 81–134.

(xv) A. ANDRONOV and S. CHAIKIN. Theory of oscillations, in Russian (Moscow, 1937).

(xvi) N. MINORSKY. *Introduction to non-linear mechanics, D. W. Taylor Model Basin Reports :* Part I — Topological methods of non-linear mechanics, *Report* 534 (1944) ; Part II—Analytical methods of non-linear mechanics, *Report* 546 (1945) ; Part III. Non-linear resonance, *Report* 558 (1946) ; Part IV. Relaxation oscillations, *Report* 564 (1946). This is mainly a summary of Russian work especially (xiii) and (xv) above. Published in one volume by J. W. Edwards, Ann Arbor, Mich., U.S.A. in 1947.

2 I (i) R. H. FOWLER. The solutions of Emden's and similar differential equations, *Monthly Notices of Royal Ast. Soc.* **91** (1931), 63–91.

(ii) C. J. ELIEZER. The hydrogen atom and the classical theory of radiation, *Proc. Cambridge Phil. Soc.* **39** (1943), 173–180.

SECT.

(iii) N. LEVINSON and O. K. SMITH. A general theorem for relaxation oscillations, *Duke Math. Journal*, **9** (1942) 382–403.

(iv) N. LEVINSON. On the existence of periodic solutions for second order differential equations with a forcing term, *Journal of Math. and Phys.* **22** (1943) 41–48.

(v) M. L. CARTWRIGHT and J. E. LITTLEWOOD. On non-linear differential equations of the second order II—The equation $\ddot{y} + kf(y)\dot{y} + g(y,k) = p(t) = p_1(t) + kp_2(t)$; $k > 0, f(y) \geq 1$. *Annals of Math.* **48** (1947), 472–494. In theorem 3 the hypotheses should be $p(t) \equiv 0$, and $f \geq 1$ for all y, and in theorem 4, $p(t) \not\equiv 0$ and $g(y)/y \geq 1$ for all y. There are also some misprints, and the term $a_3\, a_{-1}^2$ has not been considered in obtaining a_1 and k.

(vi) D. MEKSYN. The lamina boundary layer equations. II—Integration of non-linear ordinary differential equations, *Proc. Roy. Soc. A*, **192** (1948), 567–575.

2 II (i) D. R. HARTREE. Calculating machines Recent and prospective developments. *Inaugural Lecture, Cambridge*, 1947.

(ii) J. CRANK. *The Differential Analyser* (London, 1947).

(iii) J. S. KOCHLER. An electronic differential analyser, *Journal of Applied Physics*, **19** (1948), 148–155.

(iv) D. R. HARTREE. A practical method for the numerical solution of differential equations, *Proc. & Mem. Manchester Lit. & Phil.* **77**, 69–90 (1934).

(v) H. and B. S. JEFFREYS. *Mathematical Physics* (Cambridge, 1946), Chap. 9.

(vi) A. PREISMAN. *Graphical Constructions for Vacuum Tube Circuits* (New York, 1943).

(vii) Members of the Staff of the Department of Electrical Engineering, M.I.T., *Electric Circuits* (New York, 1946). There is also a book in the same series, *The Mathematics of Circuit Analysis*, in preparation.

2 III See 2 II (i) and (v) also

(i) R. V. SOUTHWELL. *Relaxation Methods in Engineering Science* (Oxford, 1940). For the method of steepest descents for differential equations, see

(ii) G. TEMPLE. General theory of relaxation applied to linear systems, *Proc. Roy. Soc.* **169**, *A* (1939), 476–500.

2 IV (i) H. POINCARÉ. *Les Méthodes Nouvelles de la Mécanique Céleste* (Paris, 1892).

(ii) A. LINDSTEDT. Differentialgleichungen der Störungstheorie, *Mémoires de l'Acad. Impériale des Sci. de St. Petersburg* (7), **31**, No. 4 (1883).

SECT.

(iii) A. LIAPOUNOV. Problème général de la stabilité du mouvement, *Annales de la Faculté des Sciences de Toulouse*, **9** (1907), trans. from Russian E. Davaux. There is also a photographic reprint of this translation in the *Annals of Mathematics Studies, No.* 17 (Princeton, 1947).

(iv) F. R. MOULTON. *Differential Equations* (New York, 1930).

(v) E. R. KELLER. Analytical methods of solving discrete non-linear problems in electrical engineering, *Trans. Amer. Inst. Elec. Eng.* **60** (1941), 1194–1199. 'Discrete' means involving ordinary differential equations as opposed to 'continuous' involving partial differential equations.

(vi) E. R. KELLER. *Mathematical Methods of Modern Engineering*, Vol. 2 (New York, 1942).

(vii) P. FATOU. Sur le mouvement d'un système soumis à des forces à courte période, *Bull. de la Soc. Math. de France*, **56** (1928), 98–139.

(viii) N. A. ARTIMIEW. Abschätzungen der Periode von nichtlineare Schwingungen mit Hilfe de methode von Integralgleichungen (in Russian with German summary), *Bull. Acad. Sci. U.S.S.R.* VII S, Nr. 8 (1934), 1231–1235.

(ix) S. LEFSCHETZ. *Lectures on differential equations, Annals of Mathematics Studies*, No. 14 (Princeton, 1946).

2 V. See Section 1 (ix), and (xvi), Part IV, also

(i) A. LIÉNARD. Étude des oscillations entretenues, *Revue Générale de l'Électricité*, **23** (1928), 901–912 and 946–954.

(ii) PH. LE CORBEILLER. The non-linear theory of the maintenance of oscillations, *Journal Inst. Elec. Eng.* **79** (1936), 361–378.

(iii) S. CHAIKIN and L. LOCHAKOW. Oscillations 'discontinues' dans un circuit à capacité et self induction, *Tech. Phys. U.S.S.R.* **2** (1935), 181–194.

(iv) M. L. CARTWRIGHT and J. E. LITTLEWOOD. On non-linear differential equations of the second order—I. The equation $\ddot{y} - k(1-y^2)\dot{y} + y = bk\lambda\cos(\lambda t + \alpha)$, k large. *Journal of London Math. Soc.* **20** (1945), 180–189.

(v) N. LEVINSON. A simple second order differential equation with singular motions, *Proc. Nat. Acad. Sci. U.S.A.* **34** (1948), 13–15.

(vi) N. LEVINSON. Perturbations of discontinuous solutions of non-linear systems of differential equations, *Proc. Nat. Acad.* **33** (1947), 214–218. This gives further references.

(vii) K. THEORDORCHIK. Contribution to the theory of synchronization of relaxatory auto-oscillations, *Comptes Rendus* (*Doklady*) *Acad. U.S.S.R.* (*N.S.*) **40** (1943), 54–57.

2 VI See Section 1 (xiv), (xv), (xvi) Part I, Section 2.I (iv), and Section 2.IV (ix), also

(i) G. D. BIRKHOFF. *Dynamical Systems* (New York, 1927).

(ii) A. DENJOY. Sur les courbes définies par les équations différentielles à la surface du tore, *Journal de Math.* (9), **11** (1932), 333–375.

(iii) N. LEVINSON. Transformation theory of non-linear differential equations of the second order, *Annals of Maths.* **45** (1944), 723–737.

3 For equation (1) see 1 (i)–(vi), (x) and

(i) B. VAN DER POL. The non-linear theory of electric oscillations, *Proc. Inst. Radio Eng.* **22** (1934), 1051–1086. This gives a summary of earlier work including 1 (ii)–(vii), (ix) and (x).

For equation (3) see 1 (xvi), Part I and

(ii) LORD RAYLEIGH. *The Theory of Sound* **1** (London, 1894), 81.

(iii) N. MINORSKY. On the non-linear phenomenon of rolling, *Proc. Nat. Acad. Sci. U.S.A.* **31** (1945), 346–349.

For equation (4) see 1 (vii)–(viii), 2.I (v), and

(iv) K. O. FRIEDRICHS and J. J. STOKER, Forced vibrations with non-linear restoring force, *Quarterly Journal of Applied Maths.* **1** (1943), 97–115. This gives a summary of earlier work with references.

(v) S. TIMOSHENKO. *Vibration Problems in Engineering*, 2nd Ed. (New York, 1943).

(vi) J. P. DEN HARTOG. *Mechanical Vibrations*, 2nd Ed. (New York, 1940).

(vii) O. BÜNEMAN. On the stability of a certain subharmonic oscillation, *Memoirs and Proc. Manchester Lit. and Phil. Soc.* **82** (1937–8), 67–68.

For equation (5) and ferromagnetic problems see 2.II (vii) and 2.IV (vi) and

(viii) A. BOYAJIAN. Mathematical analysis of non-linear circuits, *General Electric Review*, **34** (1931), Part I, 531, Part II, 745. Saturating circuits treated without differential equations by using a saturation curve consisting of two straight parts.

(ix) E. PETERSON. Harmonic production in ferromagnetic materials at low frequencies and low flux densities. *Bell System Technical Journal*, **7** (1928), 762–796.

(x) R. M. KALB and W. R. BENNETT. Ferromagnetic distortion of a two frequency wave. *Bell System Technical Journal*, **14** (1935), 322–359.

SECT.

(xi) R. V. L. HARTLEY. Oscillations in systems with non-linear reactance. *Bell System Technical Journal*, **15** (1936), 424–440.

(xii) E. PETERSON, J. M. MANLEY and L. R. WRATHALL. Magnetic generation of a group of harmonics. *Bell System Technical Journal*, **16** (1937), 437–455.

(xiii) A. TUSTIN. A method of analysing the effect of certain kinds of non-linearity in closed cycle control systems, *Journal Inst. Elec. Eng.* **94** IIA (1947), 152–160.

For work on the equation of hunting, see 2.IV (vi) and I (xvi), Part I.

For work on equation (6) see

(xiv) O. BÜNEMAN. A method for the automatic detection of maxima and minima in the response of an observing instrument, *Memoirs and Proc. Manchester Lit. and Phil.* **82** (1937–8), 95–113.

For work on systems with two degrees of freedom, see I (xvi), Part II, and

(xv) B. VAN DER POL. On oscillation hysteresis in a triode generator with two degrees of freedom, *Phil. Mag.* **43** (1922), 700–719.

For work on an equation of the third order, see 5 (iv) below ; also

(xvi) A. S. GLADWIN. The oscillation amplitude in simple valve oscillators, *Wireless Engineer* (unpublished).

4 For work on variation of frequency, see

(i) H. A. THOMAS. *Theory and Design of Thermionic Valves*. (London, 1944). This gives a list of references with the most important ones starred.

For modern non-linear problems in telecommunications, see

(ii) D.S.I.R. REPORT, Fundamental research problems of telecommunications, *Report of the Working Party on Circuitry* (1948). This contains very little mathematics.

For discussions of other problems from the physical point of view see 3 (iv) and (v) and 2.II (vii) and

(iii) O. MARTIENSSEN. Über neue Resonanzerscheinungen in Wechselstromkreisen, *Physikalische Zeitschrift*, **11** (1910), 448–460.

Physical papers which suggest unusual forms of solution are 3 (i) and the two following :

(iv) B. VAN DER POL and J. VAN DER MARK. Frequency demultiplication, *Nature*, **120** (1927), 363–364.

(v) B. VAN DER POL. Oscillations de relaxation et démultiplication de fréquence, *Réunion internationale de Phys.-Chim.-Biol., Congrès du Palais de la découverte* (Paris, 1937), *Actualités Sci. et Industrielles*.

(vii) J. D. MCCRUMM. An experimental investigation of subharmonic currents, *Trans. Amer. Inst. Elec. Eng.* **60** (1941), 533–540 and discussion 722. This contains references to earlier mathematical work on the subject.

5 See 1 (xvi) and (xi), (xii), 2.IV (i), and (iii) also

(i) P. O. PEDERSEN. Subharmonics in forced oscillations in dissipative systems, *Ingenir videnskabelige Skrifter A., No.* 35 (Copenhagen, 1933).

(ii) P. O. PEDERSEN. Subharmonics in forced oscillations in dissipative systems, *Journal of the Acoustical Soc. of America*, **6** (1935), 227–238 and 7 (1935), 64–70. This has further references, but is mainly a repetition of (i).

For a discussion of resonance phenomena in a special case see

(iii) M. L. CARTWRIGHT. Forced oscillations in nearly sinusoidal systems, *Journal Inst. Elec. Eng.* (Radio Section), **95** (1948), 88–96. This does not give proofs in full, only details of results.

(iv) *Non-linear Mechanics, Brown University Lectures* (Providence, 1942–3), published in typescript unbound including

K. O. FREIDRICHS and J. J. STOKER. Introduction to non-linear mechanics, 1–78.

K. O. FRIEDRICHS. Justification of the perturbation method, 1.1–1.15, and combination oscillations, 1.16–1.21.

P. LE CORBEILLER. Theory of prime movers, 2.1–2.18.

N. LEVINSON. Mathematical treatment of the third order differential equation of a triode oscillator, 3.1–3.9, and Liénard's method, 4.1–4.6.

(v) *Studies in non-linear vibration theory*, published in typescript, bound (Inst. for Maths. and Mech., New York University, 1946), edited by R. Courant, including :

H. J. E. ECKWEILER. Non-linear differential equations of the van der Pol type with a variety of periodic solutions.

D. A. FLANDERS and J. J. STOKER. The limit case of relaxation oscillations.

K. O. FRIEDRICHS. On non-linear vibrations of the third order.

F. JOHN. On simple harmonic vibrations of a system with non-linear characteristics.

SECT.

6 See 4 (vii), 5 (i) and (ii), 1 (xiv) and (xvi), 2.V (iv), (vi), 3 (iv), (v), (vi), 4 (iv) and (v), also

(i) I. KOGA. A new frequency transformer or frequency changer, *Proc. Inst. Radio Engineers*, **15** (1927), 669–678.

(ii) L. MANDELSTAM anl N. PAPALEXI. Über Resonanzerscheinungen bei Frequenzteilung, *Zeit. für Phys.* **73** (1932), 223–248.

(iii) J. P. DEN HARTOG and S. J. MIKINA. Forced vibrations with non-linear constants, *Trans. Amer. Soc. Mech. Eng.* **54** Section APM (1932), 157–164.

(iv) J. G. BAKER, part of the discussion on (iii) on p. 162 of the same volume and section.

(v) D. L. HERR. Oscillations in certain non-linear driven systems, *Proc. Inst. Radio Eng.* **27** (1939), 396–402.

7 See 2.V (i)–(vi) and 6.

8 See 2.II (vi) and (vii), 6 (v), also

(i) A. A. ROBB. On a graphical solution of a class of differential equations occurring in wireless telegraphy, with a note by E. V. Appleton, *Phil. Mag.* **43** (1922), 206–215.

(ii) J. C. BRAINERD and C. N. WEYGANDT. Unsymmetrical self-excited oscillations in certain simple non-linear systems, *Proc. Inst. Radio Eng.* **24** (1936), 914–922.

(iii) P. RJASIN. Einstellungs und Schwebungsprocesse bei der Mitnahme, *Tech. Physics U.S.S.R.* **2** (1935), 195–214.

(iv) V. I. GAPANOV. Zur Theorie der Mitführung bei weichen Anordnungen, *Zdurnal Tech. Fiz. U.S.S.R.* **5** (1935) (in Russian).

(v) D. R. HARTREE. The mechanical integration of differential equations, *Mathematical Gazette*, **22** (1938), 342–364. This does not give full details of his results which have not been published.

(vi) C. STØRMER. Programme for the quantitative discussion of electron orbits in the field of a magnetic dipole with applications to cosmic rays and kindred phenomena, *Comptes Rendus Congrès International des Mathematiciens* (Oslo, 1936) **1** (61–74).

9 See in particular 2 VI (i), (ii) and other works by Birkhoff, also

(i) M. CHARPENTIER. Sur quelques propriétés des courbes de M. Birkhoff, *Bull. de la Soc. Math. de France*, **62** (1934), 193–224, and other papers.

(ii) E. A. MCHARG. A differential equation, *Journal London Math. Soc.* **22** (1947), 83–85.

SECT.

(iii) T. M. CHERRY. Topological properties of the solutions of ordinary differential equations, *Amer. Journal of Math.* **59** (1937), 957–982.

(iv) M. L. CARTWRIGHT. The topological aspect of forced oscillations, *Research*, **1** (1948), 601–606.
There is also unpublished work by M. L. CARTWRIGHT and J. E. LITTLEWOOD, F. G. FRIEDLANDER, E. A. MCHARG, M. H. A. NEWMAN, G. H. REUTER.

10 See I (xvi), Part III.

11 See 2.IV (iv) and (ix), also

(i) L. BIEBERBACH. *Theorie der Differentialgleichungen* (Berlin, 1930).

(ii) E. GOURSAT. *Cours d'Analyse* (Paris, 1918), **2** and **3**.

(iii) N. W. MCLACHLAN. *Theory and Application of Mathieu Functions* (Oxford, 1947).

(iv) R. COURANT and H. ROBBINS. *What is Mathematics?* (Oxford, 1943).

(v) M. H. A. NEWMAN. *Elements of the Topology of Plane Sets of Points* (Cambridge, 1939).

vi) G. D. BIRKHOFF. Surface transformations and their dynamical applications, *Acta Math.* **43** (1922), 1–119.

12 The following references are a small but, it is hoped, a fairly representative selection of the more valuable papers published since 1941 and not mentioned earlier in this report. The selection is based mainly on reports in Mathematical Reviews.

(i) J. SHOHAT. A new analytical method of solving van der Pol's equation and certain related types of non-linear differential equations homogeneous and non-homogeneous, *Journal of Applied Physics*, **14** (1943), 40–48. This paper contains a serious error, but we include it because of the following :

(ii) J. SHOHAT. On van der Pol's equation and non-linear differential equations, *Journal of Applied Physics*, **15** (1944), 568–574.

(iii) N. G. DE BRUIJN. A note on van der Pol's equation, *Philips Research Reports*, **1** (1946), 401–406.

(iv) L. LUSTERNIK. Sur un problème limite dans la théorie des équations différentielles non-linéaires, *Comptes Rendus (Doklady) Acad. des Sci. U.S.S.R. (N.S.)* **33** (1941), 5–8.

(v) A. ANDRONOV and N. BAUTIN. Sur un cas dégénéré du problème général de régulation directe, *Comptes Rendus (Doklady) Acad. des. Sci. U.S.S.R. (N.S.)* **46** (1945), 277–279.

SECT.

(vi) L. I. MANDELSTAM. Systems with periodical coefficients with many degrees of freedom and small non-linearity, *Akad. Nauk U.S.S.R. Zdurnal Eksper Teoret Fiz*, **15** (1945), 605–612 (in Russian with English summary).

(vii) B. V. BULGAKOV. On the method of van der Pol and its application to non-linear systems, *Journal Franklin Inst.* **241** (1946), 31–54, and other papers.

(viii) I. M. VOLK. Elastic oscillations with damping proportional to a power of the velocity, *Akad. Nauk. S.S.S.R. Prikl. Mat. Mech.* **10** (1946), 125–134 (in Russian with English summary).

(ix) K. THEODORCIK. The laws of co-existence of frequencies in soft auto-oscillating systems, *Bull. Acad. Sci. U.S.S.R. Cl. Sci. Tech.* (1946), 385–388, and other papers on various topics of non-linear systems.

(x) N. OTROKOV. Sur le nombre des cycles limites au voisinage d'un foyer, *Comptes Rendus (Doklady) Acad. Sci. U.S.S.R. (N.S.)* **43** (1944), 98–101.

(xi) A. I. LOURIE and V. N. POSTNIKOV. Concerning the theory of stability of regulating systems, *Akad. Nauk. S.S.S.R. Prikl. Mat. Mech.* **8** (1944), 246–248.

(xii) A. ANDRONOV and A. MAYER. Le problème de Mises dans la théorie de la régulation directe et la théorie des transformations ponctuelles des surfaces, *Comptes Rendus (Doklady) Acad. Sci. U.S.S.R.* **43** (1944), 54–58.

(xiii) I. S. KOUKLESS. Sur les conditions nécessaires et suffisantes pour l'existence d'un centre, *Comptes Rendus (Doklady) Acad. Sci. U.S.S.R. (N.S.)* **42** (1944), 160–163, and other papers on similar topics.

(xiv) H. WEYL. Concerning a classical problem in the theory of singular points of ordinary differential equations, *Revista Ci. Lima*, **45** (1944), 73–112 = *Actas Acad. Ci. Lima*, **7** (1944), 21–60.

SECT.

(xv) C. L. SIEGEL. Note on differential equations on the torus, *Annals of Mathematics* (2) **46** (1945), 423–428.

(xvi) J. R. TILLMAN. Valve oscillators, *Wireless Engineer*, **24** (1947), 357–371.

(xvii) R. B. MEUSER and E. E. WEIBEL. Vibration of a non-linear system during acceleration through resonance, *Journal of Applied Mechanics*, **15** (1948), 21–24.

(xviii) J. MÜLLER-STROBEL, Lösung des Gleichungssystems der pendeln der Synchronmaschine. *Archiv für Electrotechnik*, **36** (1948), 399–417.

(xix) D. G. TUCKER. Forced oscillations in oscillator circuits and the synchronization of oscillators, *Journal Inst. Elec. Eng.* **92**, III (1945), 226–234.

(xx) W. WENKE. Die Instabilität linearer und nicht linearer Schwingingen (Mitnahmeschwingungen), *Hochfrequentztechnik und Electroakustik*, **55** (1940), 94–101 and 109–120.

(xxi) Z. BULTEWSKI. Sur les intégrales oscillantes et bornées d'une équation différentielle du second ordre, *Ann. Scuola Norm. Super Pisa* (2), **9** (1940), 187–200.

(xxii) H. LEMKE. Über die Gleichungen der Gaskugeln und andere Differentialgleichungen von ähnlicher Form, *Journ. für reine u. angewandte Math.* **183** (1941), 197–231.

(xxiii) N. MINORSKY. Self-excited mechanical oscillations, *Journal of Applied Physics*, **19** (1948), 332–338.

(xxiv) E. G. KELLER. Some present non-linear problems of electrical and aeronautical industries, *Quarterly Journal of Applied Maths.* **2** (1944), 72–86.

(xxv) E. E. WEIBEL, N. M. COKYUCEL and R. E. BLAU. A mechanical analyser for the solution of vibration problems of a single degree of freedom, *Journal of Applied Mechanics*, **15** (1948), 146–150.

Note—The *Journal of Applied Mechanics* is bound as section APM of the *Transactions of the American Society of Mechanical Engineers.*

NAME INDEX

Andronov—and Bautin, 12 (v)
  and Chaikin 1 (xv)
  and Mayer 12 (xii)
  see also Mandelstam
Appleton 1 (ii, vii)
  and Greaves, 1 (iii), 5
  and v. d. Pol 1 (vi)
Artimiev, 2.IV (viii)

Baker, 6 (iv)
Bautin, *see* Andronov
Bendixson, 11
Bennett, *see* Kalb
Bieberbach, 11 (i)
Birkhoff, 2.VI (i), 9, 11 (vi)
Blau, *see* Weibel, Cokyucel and Blau.
Bogoliuboff, *see* Kryloff
Boyajian, 3 (viii)
Brainerd—and Weygandt, 8 (ii)
Brown Univ., 5 (iv)
de Bruijn, 12 (iii)
Bulgakov, 12 (vii)
Bultewski, 12 (xxi)
Büneman, 3 (vii, xiv)

Cartwright, 5 (iii), 9 (iv)
and Littlewood, 2.I (v), 2.V (iv), 99,
Chaikin—and Lochakow, 2.V (iii)
see also Andronov, Mandelstam
Charpentier, 9 (i)
Cherry, 9 (iii)
Cokyucel, *see* Weibel, Cokyucel and Blau.
Courant (ed.), 5 (v)
and Robbins, 11 (iv)
Crank, 2.II (ii)

Davaux (tr.), 2.IV (iii)
den Hartog, 3 (vi)
and Mikina, 6 (iii)
Denjoy, 2.VI (ii), 5, 9
D.S.I.R., 4 (ii)
Duffing, 1 (viii)

Eckweiler, 5 (v)
Eliezer, 2.I (ii)

Fatou, 2.IV (vii)
Flanders—and Stoker, 5 (v)
Fowler, 2.I (i)
Friedlander, 9
Friedrichs, 5 (iv, v)
and Stoker, 3 (iv), 5 (iv)

Gapanov, 8 (iv)
Gladwin, 3 (xvi), 4
Goursat, 11 (ii)
Greaves, 1 (iv, v)
see also Appleton

Hartley, 3 (xi)
Hartree, 1, 2.II (i, iv), 8 (v)
Herr, 6 (v), 8
Hill, 10, 11

Jeffreys—and Jeffreys, 2.II (v)
John, 5 (v)

Kalb—and Bennett, 3 (x)
Keller, 2.IV (v, vi), 12 (xxiv)
Kochler, 2.II (iii)
Koga, 6 (i)
Koukless, 12 (xiii)
Kryloff—and Bogoliuboff, 1 (xi, xii, xiii), 5

le Corbeiller, 2.V (ii), 5 (iv)
Lefschetz, 2.IV (ix) ; (tr.), 1 (xii)
Lemke, 12 (xxii)
Levinson, 2.I (iv), 2.V (v, vi), 2.VI (iii), 3, 5 (iv)
and Smith, 2.I (iii), 9
Liapounov, 2.IV (iii), 5, 11
Liénard, 2.V (i), 9
Lindstedt, 2.IV (ii)
Littlewood, *see* Cartwright
Lochakow, *see* Chaikin
Lourie—and Postnikov, 12 (xi)
Lusternik, 12, (iv)

McCrumm, 4 (vii)
McHarg, 9 (ii), 9
McLachlan, 11 (iii)
Mandelstam, 12 (vi)
and Papalexi, 6 (ii)
Papalexi, Andronov, Chaikin, and Witt, 1 (xiv), 5
Manley, *see* Peterson
Martienssen, 4 (iii)
Mass. Inst. Tech., 2.II (vii)
Mathieu, 10, 11
Mayer, *see* Andronov
Meksyn, 2.I (vi)
Meuser—and Weibel, 12 (xvii)
Mikina, *see* den Hartog
Minorsky, 1 (xvi), 3 (iii), 5, 12 (xxiii)
Moulton, 2.IV (iv)
Müller-Strobel, 12 (xviii)

New York Inst. Math., 5 (v)
Newman, 9, 11 (v)
Nicolson, 1

Otrokov, 12 (x)

Papalexi, *see* Mandelstam
Pedersen, 5 (i, ii), 6
Peterson, 3 (ix)
Manly and Wrathall, 3 (xii)
Poincaré, 2.IV (i), 2.VI, 5, 11
Postnikov, *see* Lourie
Preisman, 2.II (vi)

Rayleigh, 3 (ii)
Reuter, 9
Rjasin, 8 (iii)
Robb 8 (i)
Robbins, *see* Courant

Shohat, 12 (i, ii)
Siegel, 12 (xv)
Smith, *see* Levinson
Southwell, 2.III (i)
Stoker, *see* Flanders, Friedrichs
Størmer, 8 (vi)

Temple, 2.III (ii)
Theordorchik, 2.V (vii), 6, 12 (ix)
Thomas, 4 (i)
Tillman, 12 (xvi)
Timoshenko, 3 (v)
Tucker, 12 (xix)
Tustin, 3 (xiii)

van der Mark, *see* van der Pol
van der Pol, 1 (i, ix, x), 2.V, 3 (i, xv), 4 (v), 12
and van der Mark, 4 (iv), 6, 8
see also Appleton
Volk, 12 (viii)

Weibel, Cokyucel and Blau, 12 (xxv).
Weibel, *see* Meuser
Wenke, 12 (xx)
Weygandt, *see* Brainerd
Weyl, 12 (xiv)
Witt, *see* Mandelstam
Wrathall, *see* Peterson

SECTION J.—PSYCHOLOGY

ABSTRACTS OF COMMUNICATIONS

READ TO THE SECTION AT THE ANNUAL MEETING
OF THE ASSOCIATION IN BRIGHTON

SEPTEMBER 9, 1948 (MORNING)

Race and colour vision

By Dr. R. W. Pickford

A considerable amount of evidence has been collected in the past, showing that red-green blindness is decidedly less common among the peoples of West African, American Indian and other groups, such as the Papuans and Fijians, than it is among Caucasian peoples. Most of his evidence has been collected with the use of Holmgren's wool test or Lovibond's tintometer, as by Rivers, or with the Ishihara test, as by Clements and Geddes. Using the wool test and the tintometer, Rivers also showed that there is a widespread tendency among primitive races for weakness in sensitivity to blue, and this was reflected frequently in confusions of blue with green and the use of the same name for these colours.

Without doubt the development of a more efficient system of colour vision testing is of great scientific importance, and would lead to the discovery of many facts which are not clearly revealed by tests hitherto employed. With the use of data collected by means of pseudo-isochromatic tables of the Stilling-Ishihara type, Vernon and Straker have shown that red-green blindness is more common in the South and West of the British Isles, where earlier dark-skinned inhabitants may have been pushed by later Nordic invaders. Burt has also given evidence of a connection between red-green defects and darkness of skin pigmentation, but Pickford has shown that in a single area, the S.W. part of Scotland, there was no such relationship, which may be the result of racial purity in that area. With adequate tests, however, it was shown that dark-skinned races were less sensitive to yellow and blue than Europeans : Dravidians less than other Indians, and West Africans less than Dravidians.

Training methods for the partially sighted

By Dr. L. G. Fuchs

Training of this hitherto somewhat neglected category of the disabled is treated as part of all industrial training. Two tasks arise in this particular case : (i) to assist in the adjustment to the physical handicap of partial sight (definition) ; (ii) to devise methods that should enable such persons to perform every task as skill.

The first task being beyond the scope of the paper, the second only is considered. The trainer should not make the mistake of the medical men by saying—' It is all up to you.' Achievement in skilled performance is an important aid towards successful adjustment. Success depends on confident co-operation between the disabled and his trainer.

The method used is a variation of an adaptation of the dynamic training so far only validated for partially sighted. It is based on a strong motivation derived from the relationship between operator and his job and a much closer analysis than is usually the case.

The analysis of the task is not only into T.W.I. steps that further the progress of the task, but includes :

1. Arrangement of requisite motions, with regard to effort saving (lay-out) and rhythm.
2. Sensory requirements (sincere perception). Signals from all modalities.
3. Mental processes—
   (*a*) Time and space perception;
   (*b*) Conscious attitudes ;
   (*c*) Higher processes — memorising, judging and deciding.
4. Assessment of visual requirements (with medical aid).
5. Assessment of—
   (*a*) those elements that should be performed visually ;
   (*b*) those that must be performed by the tactual-kinaesthetic method.

This training should be given in stages, which in turn, should act as a motivation. It should be applied to each practice level.

Assistance should be given to divide each task in the life situation into those to be performed visually and those to be carried out without vision.

The psychology of anti-semitism

By Dr. H. J. Eysenck

Anti-semitism is a social phenomenon which is amenable to scientific analysis.

Such analysis does not aim at making value judgments or at elaboration of ethical prescriptions but is concerned merely with certain factual points, such as, for instance, the personality qualities of the person holding anti-semitic attitudes, the general social-political outlook of the anti-semite, and the distribution of anti-semitic attitudes in the population. Studies of this type have been carried out during the past years in America, with results which are interesting and suggestive but not conclusive because of the very small number of people involved and the subjective type of test used. Recently, more objective studies carried out at the Maudsley Hospital have confirmed and extended these earlier results. They have shown a definite correlation to exist between anti-semitism and neuroticism (lack of emotional stability), and they have also shown considerable correlations between anti-semitism and voting behaviour in political situations. These findings show that anti-semitism is a social attitude which is susceptible to accurate measurement and that its causation and its structure can be made the subject of scientific analysis.

Presidential Address

An address on *Present-day trends in British psychology* was given by the President of the Section, Professor A. Rex Knight. (The full text appeared in *The Advancement of Science*, No. 19, pp. 254–261.

SEPTEMBER 10, 1948 (MORNING)

The Section took part with the Physiology Section in a discussion on *The problems of old age* which is reported elsewhere in *The Advancement of Science.*

SEPTEMBER 10, 1948 (AFTERNOON)

The development of imaginative construction in children

By Miss M. D. Vernon

A group of 68 Grammar School girls aged 10–12 were shown individually four pictures illustrating fairy stories, and asked to ' make up a story about what is happening in this picture.' About 8 per cent. of the responses were really good imaginative constructions. At the other end of the scale, 12 per cent. of the responses were purely descriptive, not real stories at all ; 7 per cent. introduced description of unimportant detail ; and 20 per cent., though they could be called stories, were brief and banal, with little real imaginative construction. The remaining 47 per cent. did show definite imagination, but also some logical inconsistency or omission of essential features of the picture. They indicated the difficulty encountered in constructing a story, consistent and logical as far as regards the ' fairy tale ' convention, which satisfactorily ' explained ' the incidents depicted. Some children also attributed incongruous feelings or undue ineffectiveness of action to the characters in their stories. There was evidence to show that such children might be suffering from emotional difficulties, and that their cognitive abilities might be dominated or inhibited by processes arising in the unconscious mind.

The adolescent and the cinema

The remainder of the afternoon was devoted to a session on *The adolescent and the cinema* in which three papers were given.

In a paper on *Cinema attendance among adolescents* Mr. N. D. Dodman said that 60 per cent. of all the subjects (aged 13–16) of an inquiry in the Birmingham area visited cinemas at least once weekly. Modern school pupils, of whom 50 per cent. went twice or more weekly, went twice as frequently as Grammar School pupils. The differences, statistically significant, possibly reflected not only variation in intellectual level, but also such social factors as degree of parental interest in leisure activities, lack of home comfort in large families, restricted interest in other forms of social activities on the part of the adolescents themselves, or even lack of leadership.

All groups visited cinemas principally at week-ends. Twice as many boys as girls went on Sundays ; the percentage of Modern School pupils attending on Sundays was three times that found among Grammar School pupils.

Expenditure on cinema-going varied with class, and showed a tendency to variation with sex.

The trailer predominated as the means of choosing films, but the use of newspaper reviews by Grammar School pupils increased with age.

The majority of both films and cinema programmes were rated officially as unsuitable for unaccompanied adolescents, but from investigations it appeared that the under 16's had little difficulty in gaining admission to see them.

In a paper on *The Content of Films seen by Adolescents during a Fortnight*, Miss B. Kesterton said that her information was based mainly on an investigation carried on in West Bromwich, a county town just outside Birmingham, from which detailed information was available.

The purpose of the paper was to analyse the content of a number of films seen by 300 adolescents in a given fortnight, showing what types of films attracted most children

and what motives, values, backgrounds and standards were stressed in the films.

A brief survey was given of the types of films shown during the fortnight and of those visited by adolescents. The percentage of 'A' category films seen by children was discussed. The paper, also, contained an analysis of the sets of the films, occupations of the chief characters, motives which inspired the actors and actresses, the treatment of social conscience or minority opinion in the film, the amount of emphasis laid on luxury and self-display as compared with mental and manual work, the appeal through show of violence or sentimentality and, finally, the attitude taken to love between the sexes.

Throughout the analysis, the percentage of children seeing each of these factors, was noted. From this basis, it was easier to relate the emotional reactions and disturbances of adolescents to specific incidents in the films which they saw.

In a paper on *The Emotional and Social Effects of Films on Adolescents* Mr. W. A. Simson said that the detailed analysis of the emotional reactions of adolescents to 12 films (each 'population' exceeding 36) showed that the effects were very closely dependent upon the content and emphasis of the individual film. Girls appeared to be more suggestible to stimuli in films, especially where the inhibitive impulse of sadness was aroused. Girls tended to remember incidents better than boys. More boys than girls (31 % to 20 %) felt more loving towards friends of the other sex, more girls than boys felt more loving towards parents (19 % to 11 %) and wished to help other people (36 % to 24 %). Some 35 % of each sex wished to become characters. Only 7 % of adolescents longed for more money, but more boys than girls (36 % to 22 %) found life dull, and more girls than boys (35 % to 27 %) wished to travel. About 17 % reported being shocked. Judgments about 'life-likeness' were comparable with those of adults.

1261 boys and 899 girls answered the questions about imitation. The percentages of boys and girls who thought that *boys* imitated items in the films were not significantly different (dancing and love-making excepted). The percentages of boys and girls for imitation by *girls* had the same trend, but the girls' percentages were significantly higher for all items, except amusements, and love-making (which was significantly lower). 53–83 % of adolescents thought girls imitated make-up, hair-style and dress; 20 %–38 % thought boys imitated hair-style and dress. About 50 % of each sex imitated ways of behaving, talking and amusement. The figures for imitation of dancing and love-making appeared to be complicated by the different attitudes of boys and girls to these activities, and by the operation of social conventions.

September 13, 1948 (Morning)

The relations between Anthropology, Psychology and Sociology

By Prof. T. H. Pear

Presumably, the simplest meaning of Anthropology is the Science of Man. Ideally, therefore, it would include (a) individual psychology; the study of experience, and of behaviour in so far as it throws light upon experience (b) social psychology; the study of experience and behaviour in so far as they are affected by social relations (for some psychologists, (a) and (b) are indistinguishable) and (c) sociology, the study 'of the supra-individual determinants of behaviour; of human relations and institutions and of social behaviour under the "natural" conditions of human society.'

Some workers in this field would not assent to this differentiation, and in practice there are many overlappings.

This lack of a conspectus leads to misunderstanding, unnecessary duplication of effort, premature hardening of concepts inside the sub-departments, the insulation of thought and the jealousies inseparable from the creation of 'schools,' and much ignorance of relevant work in adjacent spheres.

Recently, in *The Cultural Background of Personality*, Prof. Ralph Linton has surveyed the whole field from an anthropological point of view, and attempted to lay the foundations of a common language. The present paper seeks to supplement this from the direction of social psychology.

In England today there is a special need for some agreed delineation of the spheres of the three studies and for a rapprochement of anthropologists, sociologists and psychologists.

The development of guidance in Australia

By Mr. H. S. Williams

The paper dealt with the development of general educational and vocational guidance services rather than of clinics.

A brief survey of the pre-war situation focussed attention on the work carried out in New South Wales, since that state had by far the most adequately organised guidance services up to 1939. These included a counselling service in the schools and a Vocational Guidance Bureau in the State Department of Labour and Industry.

War-time developments discussed included the vocational guidance work with school-leavers initiated in Western Australia by the Education Department and the Commonwealth Department of Labour and National Service. This programme was considered in some detail and its expansion into a general psychological service for schools outlined. Work in the Armed Services was considered mainly from the point of view of guidance in relation to rehabilitation training and employment.

Reference was made to the establishment of the Vocational Guidance Division of the Commonwealth Employment Service and to work being carried out under the aegis of the recently established Commonwealth Office of Education.

Brief comment was made on the selection and training of guidance personnel and on the role of the Australian Council for Educational Research as a 'servicing' and research organisation.

Psychological characteristics of Peptic Ulcer patients

By Mr. P. A. D. Gardner

Physicians have long regarded the patient with a peptic ulcer as a special type of person, less well adjusted in general than patients with other illnesses. Distinguishing characteristics of the ulcer patient are said to include (1) a particular facial appearance, (2) intense mental and physical activity and (3) a particular reaction to their illness.

The present paper is concerned with (1) how clearly these characteristics distinguish ulcer from non-ulcer patients, (2) further distinguishing characteristics and (3) early adjustment of the ulcer patient before the onset of the ulcer.

Some 300 patients selected at random were interviewed and ratings made of a number of traits. A personality questionnaire and McDougall's Dotting Machine were done and body measurements taken. Roughly half the patients were peptic ulcer patients, the remainder being a mixed group of 'other' illnesses. During interview the nature of the patient's illness was not known and not discussed and an attempt was made to divide ulcer from non-ulcer patients on personality features alone.

Results and discussion: the accuracy with which ulcer and non-ulcer patients can be distinguished on personality characteristics alone. The important characteristics: the ulcer 'facies': intensity of 'drive,' worry: anxiety: intensity of emotion and its expression: introversion: attitudes to work, sex, illness etc.; adjustments in childhood.

Psychological control of fear

By Mrs. F. M. Austin

Man's life is a constant struggle to establish and maintain a satisfactory relationship between himself and his environment through self-mastery and mastery of the environment. Man struggles to survive and to progress. Fear often hinders him. Control is necessary.

This paper is concerned with normal fear. The criterion of normality is its universal liability to arise in certain fairly well-defined circumstances. Some stimuli which tend to arouse fear are: certain noises, vibrations, and movements; loss of security; sense of suffocation or other danger. Everyday life provides numerous examples.

In the recent war the psychologist had exceptional opportunities to observe many common preventives and correctives in action. Easily observable were: self-assertiveness, pugnacity, curiosity, gregariousness, protectiveness, reliance on others, the doing of something, experience, knowledge, habit, and in addition, other influences like ideals, ambitions, self-approval, sense of duty, social approval.

These influences interact. None is always predominant. The whole situation in which the fear-stimuli occur determines the behaviour of the individual or group concerned. To predict and control fear general and detailed knowledge of environment and people is required.

The adult's pattern of emotional behaviour is not easily altered. It depends on the integration and balance of personality. The foundations of morale are laid down in childhood where control, integration and direction of emotions begin.

September 13, 1948 (Afternoon)

Some problems involved in the use of the objective test as a measuring device

By Dr. E. A. Peel

The assumptions which underlie the construction of the objective mental test and the conditions under which such a psychometric device approximates to a measure in the physical sense need consideration. The application of an objective test containing items which have previously been evaluated for 'difficulty' consists fundamentally of a comparison of two classes of persons in respect of their response to the test situations.

Furthermore, this measuring device can be shown to approach the rigour of physical measurement in so far as 'item difficulty' conforms to the conditions required for physical measures. Under these conditions the estimated 'item difficulties' should be linear and additive. Such requirements

tend to be fulfilled if the ' item difficulties ' are derived from a *rectangular distribution* of persons whose range of ability and fineness of measurements of ability tend to exceed the range and fineness of the ' item difficulties.' This condition, that the population of persons used to obtain the ' item difficulties ' should be rectangular, can be exemplified by simple examples, drawn from physical measurement, of estimating lengths of objects.

The relationship between levels of reading comprehension and word recognition in secondary modern school pupils

By Miss D. M. Lampard

Two thousand eleven year olds, and twenty-five hundred fourteen year olds in thirty-eight schools (boys, girls and mixed) in urban and suburban areas were given two reading tests. A percentage of these were then given a word recognition test, a verbal intelligence test and a non-verbal intelligence test.

The aim of the study was to estimate the relationships between levels of reading comprehension and word recognition of eleven and fourteen year olds in Secondary Schools. This was part of a survey of the University of Birmingham Institute of Education to investigate the abilities and attainments of Secondary Modern School pupils in order to lay the foundation for experimentation in teaching methods and curricula.

An investigation of post-war reading ability

By Dr. P. E. Vernon

The author said that complaints were often heard regarding the ' illiteracy ' of post-war school leavers and recruits to the Services. In order to survey the extent of the problem a new silent reading test had been devised by Dr. A. F. Watts and the author, and calibrated by comparison with several reliable pre-war tests. The psychological principles of construction and the methods of item analysis and standardisation were described.

Application of the completed test to some two thousand children and a thousand 18 year old males had indicated that :

(1) there was an average decline of over a year in Reading Ages from pre-war standards ;

(2) the proportion of semi-literates (R.A. under 9 yrs.) was about 4 per cent. in 15 year children and in Army recruits instead of the 10–20 per cent, which had been quoted by other writers ;

(3) the proportion ranged from 0 per cent. in Grammar, Technical and Selective schools to 14 per cent. in some rural schools ;

(4) there did *not* appear to be the same decline in reading ability between 14 and 18 as that reported by the author in spelling and arithmetic abilities.

September 14, 1948 (Morning)

The nature of incentives

In a discussion on this subject the main speakers were Mr. Nigel Balchin, Professor C. A. Mace, Mr. Adam Curle and Mr. Alec Rodger.

Mr. Nigel Balchin remarked on the absence of any general body of theory about incentives, and suggested the reason for this. Industry's pre-occupation with financial incentives, and the origin of this pre-occupation, were examined. It was submitted that the financial incentive had now been so weakened that it must be reinforced by others. The ' more leisure ' theory was criticised and its value, *as an incentive*, questioned. It was maintained that the desires for a high material standard of life and for happy activity could only be squared by making work itself the happy activity. The problem of incentives therefore became nothing less than the total problem of human motivation. The failure of industry to study and apply the factors affecting human motivation was illustrated by reference to McDougall's work on instincts, and the concepts of Freud.

The size and length of the work envisaged, and its inability to solve the immediate national problem were admitted. But it was nevertheless maintained that it was the business of scientists to tackle it. An effort was made to distinguish between the task of the scientist and that of industrial management in this matter, and an appeal was made to the psychologist to stop trying to manage other people's factories, and to concentrate on the discovery of the principles on which they should be managed.

Professor C. A. Mace said that the discussion of the problems of incentive had reached a stage at which it was important to distinguish the lack of knowledge from the lack of will to act on what was already known There was still much that was not known, but there was also much that could be done.

Why was action not taken on what was already known ? The answer in part was that a stage had been reached at which the development of science and the development of industrial procedures impinged upon politics and religion, and action was subject to emotional inhibitions.

There was no very short-term policy which offered a promise of meeting the present demand for a stronger ' will to work.' The will to work depended on underlying conditions of good ' morale,' and both good and bad morale were the products, in the main, of

slowly acting causes. The foundation of a satisfactory incentive system lay in vocational guidance, vocational education, and the organisation of a social and industrial order in which co-operation sprang from purposes genuinely shared by those who needed to co-operate.

A distinction should be drawn between the function of the scientist and the function of industrial management; but having drawn this distinction, the question next to arise was: How could the representative of science and the representative of management most efficiently co-operate? Solutions would not be reached by scientists in advance of practical industrial experiment, and solution would not be reached by blind experiment. The situation demanded research of the 'operational type' in which management, with scientists in an advisory capacity, planned and carried out *long-term* programmes for the improvement of morale, the progress of which might be checked and assessed in a systematic way.

Mr. Curle pointed out that only in modern society was there need to discuss incentives; in the primitive society necessary work was as automatic as sex and eating. The reasons for this were considered. They were mainly due to the closely-knit and internally consistent nature of primitive society. Modern society, however, was segmented from rapid and unequal change in its various parts. Consequently attitudes holding good in one sphere were often not valid in another. This condition created confusion and conflict in the individual, who frequently tried to escape further hurt from an injuring society by partial withdrawal or by limiting emotional contacts and responsibility. This adversely affected not only working, but also social and domestic life. There was consequently little value in localised or temporary expedients. Only a different form of society would make it once more unnecessary to discuss incentives.

There was, however, some evidence that already, on a small scale, it was possible to affect the whole life space of an individual or group in such a way that all spheres of life were enriched. This enrichment replaced the automatic traditionalism of primitive society, by an unanxious appreciation of group needs. This might be described as the psychological basis of democracy.

A plea was made for the co-operation of all social science disciplines in making this type of work more widespread and effective.

Mr. Alec Rodger said that the Oxford English Dictionary suggested that an incentive was something that incited, urged, stirred up. This was the sort of meaning attached to the word in common speech, and it seemed desirable that it should normally be used in some such simple sense as this. It was passing rather than permanent in its effects; it was usually pleasant or unpleasant; and it was either a pull or a push, a prise or a prod.

In general, clear statements of the meanings of the words used in discussions of incentives were necessary, because in this field differences of idiom were numerous. These differences created serious problems, because their roots ran deep; they sprung from fundamental differences in outlook on the whole business of human motivation. Psychologists would not be able to make a satisfactory contribution to the solution of pressing industrial productivity problems until they gave this question of terminology very careful attention.

Mr. Balchin's suggestion that some psychologists were trying to manage other people's businesses for them was surprising but it was true that very often it was difficult to determine where the function of the technical adviser ended and the function of his managerial colleagues began. Sometimes the adviser could discern principles on which businesses should be conducted only by taking on administrative duties himself. Moreover, to a large extent administrative problems were technical problems, and *vice versa*.

September 14, 1948 (Afternoon)

Some concepts and techniques relating to problems of social change

By Mr. B. S. Morris

Social change is but a small part of the not easily defined field of social psychology. The work of the Institute of Human Relations has been concerned with the study of social change by direct participation in it, that is to say, the Institute has collaborated, in industry and elsewhere, in attempting to provide methods of arriving at solutions to problems actually occurring at the present time. It can do this only in certain areas. Major field forces, such as the general economic situation, national policy and international affairs, determine social events in a way which provide the social scientist with little scope to influence them. But within the limits determined by these major field forces, there are problems on which the advice of the social scientist is sought and requested. These opportunities for the social scientist occur in areas where the major field forces are already determining that some change must take place.

It is at the stage when his advice is directly sought that the social scientist is given the kind of needed advisory role which offers him the very best opportunities for carrying

out his researches and developing his own skill. The application of his skill and knowledge is then followed by a process of 'attenuation.' That is, the highest level of technical skill is required for the initial appreciation of the problem, but when the social scientist's suggestions are embodied in some practical scheme, and the first pilot model is set up, such as the first War Office Selection Board, or the first Civil Resettlement Unit, it is then inevitable that, as the size of the project develops, the work is carried on by para-technical people—people who, although not primarily technicians in their own right, are 'technical' in so far as they have absorbed the experience and the skills made available by the pilot model. The pilot model itself is modified by the community to bring it within the cultural norm, so that it becomes an organic part of that community, and when this has happened, resistences develop against further change. The pilot model has become a stereotype and deviations from it are not desired—yet, as was experienced in W.O.S.B.'s, this settling down, this hardening, does not necessarily mean that development is wholly checked, because there are 'side effects' in neighbouring fields which lead to fresh demands and the creation of new developments elsewhere.

The Institute has made use of a number of techniques, 'permissive communities,' consumer participation' and various types of group discussion as used in C.R.U.'s and W.O.S.B.'s and developed by Dr. Bion in his analytic and therapeutic groups. There is considerable room for investigation of the situations where these techniques can be applied, and a general theory is needed to provide a view of behaviour as the resultant of the interaction of internal forces in the individual and external forces in the social field.

Interpretive group discussion as a method of facilitating social change

By Dr. Elliott Jaques

The paper was a progress report on the use of interpretive group discussions to facilitate social change in communities which request outside assistance in overcoming difficulties in intergroup relationships. The method of interpretive group discussion was described, and the principles upon which its use is based were outlined. The development of a number of projects was then recounted to demonstrate the use of the method in field situations.

Background studies in selection for high-grade appointments

By Dr. E. O. Mercer

Personnel selection as a branch of applied psychology has to base itself on continuous investigation if it is not to become automatism. Some of the fundamental psychological research has been carried out independently in the universities and much information can be drawn from previous selection experience. Many studies, however, must be derived from the selection procedure itself, be conducted by those who understand its problems, and remain associated with it. The studies which most psychologists would require for a piece of high-grade selection fall into three groups:

1. Studies of the job—by factor analysis of duties, by systematic studies of previous cases of success and failure, by descriptive notes, visits and discussions;
2. Studies of the candidates for selection—their characteristics, and analysis of the variance in their performance;
3. Studies of the selection process itself—not only in 'item analysis,' establishment of reliability, and standardisation of tests used, but by factor analysis to throw light on what the procedure takes chiefly into account, and by validation against such criteria as reports on the training and work of those selected. Some such enquiries will be preliminary, some concurrent, some retrospective; many are continuous.

New-type examinations in technical education

By Adrian Gilbert

In this research, the Building Industry Research Unit of the Medical Research Council has been concerned with the application of new-type tests in two fields of technical training in the Building Industry, those of craft apprenticeship and foremanship. Each field presents specific training problems, but a common difficulty is the acquisition of minimum amounts of theoretical knowledge and information by practical men to whom 'book learning' is a severe task. Experiments with new-type tests are being made with the object of giving those responsible for this training additional means of examination—one which in many instances is superior to those already being used.

The experiments indicate the chief value of new-type tests in this field to lie in the statistical reliability of their scores and the ease with which they can be used on candidates whose common disability is unfacility of written verbal expression. The experiments show that the tests have three possible uses, as a general check on the total knowledge possessed by a trainee both at the beginning and the end of his course, as specific checks on the learning of restricted material and as standardised psychological tests of attainment.

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